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What – and How – Form Knows: Form, Formalism, and Mathematics in Virginia Woolf's Fiction

Introduction: Extending Concepts of Form to Mathematics

"Logic bears on its modern banner, The [sic] form of thought, the whole form, and nothing but the form" (De Morgan 1864, 177). Augustus De Morgan's remark, first made in a talk in 1858, also applies to modern mathematics: mathematics is a formal science that is not concerned with physical phenomena like the natural sciences but refers to abstract structures described by sign systems. Despite the consequent relevance of maths for questions about form and knowledge, literary studies have only begun to investigate its role in this context.[1] This paper examines the place of mathematics in Virginia Woolf's conception and practice of formalist literature, tracing her engagement with maths in her early novel *Night and Day* (1919) and her later work *To the Lighthouse* (1927). Woolf's novels draw on concrete mathematical forms such as the triangle, but, more importantly, they explore how maths can help us understand what – and how – form knows. Detailing Woolf's modernist explorations of formalist mathematics and her experiments with knowledge gained through formal properties of fiction, the paper clarifies the role of maths for Woolf's innovations in modernist literary form and reveals intersections between mathematical and literary forms of knowing.

The formal science of mathematics has traditionally been seen as a field of absolute or certain knowledge, and, as such, suggests itself as a fruitful object of inquiry when investigating the epistemological potential of form. Yet, the usefulness of turning to maths when studying literary form might be less obvious. Indeed, literature and maths are often perceived as antithetical, and attention to the role of mathematics in fictional texts has only begun to pick up in the last decades: the use of mathematical and statistical methods has increased with a focus on big data and digital humanities, and research on the thematic, metaphorical, and formal functions of maths in literary texts has grown to the point of beginning to constitute a modest, but distinct, field of literature and mathematics studies. Among the works demonstrating that literary form and mathematical ideas are more closely related than commonly assumed is Henry S. Turner's monograph *The English Renaissance Stage: Geometry, Poetics, and the Practical Spatial Arts 1580-1630* (2006), which asserts the importance of mathematical ideas of form for early modern writers:

> I began with what seemed like a simple question – how did early modern poets and playwrights understand their own formal practice? – but soon found that several different

1 For recent research on literature and mathematics, see Brits (2018); Doxiadis and Mazur (2012); Engelhardt (2018); Gamwell (2016); Hickman (2005); Jenkins (2007); Throesch (2017); Tubbs (2014); Wickman (2016).

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> *ideas about form* and several different *examples of form* circulated among groups of people that I never expected to find associated with one another and across domains of activity that literary critics rarely considered. English playwrights, it turned out, were drawing […] from contemporary developments in early modern technology, applied mathematics, and prescientific thought. (2010, 581; original emphasis; see also Turner 2006, 3)

In a paper from 2010, Turner reflects on form more generally and, specifically, on lessons that historians of science could learn from literature and *vice versa*. He lists four common categories that "literary critics mean today when they talk about 'form'" (2010, 579): stylistic notions of form, such as verbal patterning, metrical language, and types of narration; secondly, structural notions of form that include plot and stanzaic structures; thirdly, material notions such as the page size and layout; and fourthly, social notions of form that refer not to textual phenomena but include class organisation, economic production, and political systems (580-581). Yet, drawing on his own research on early modern playwrights, Turner identifies a need to go beyond these common notions of form, for example by including the mathematical:

> in my view one of the most pressing tasks confronting literary criticism today will be to expand concepts of form beyond linguistic and textualist models. This claim may sound paradoxical [… seeing] that literary critics are primarily concerned with problems of language. […] But this tendency is precisely what inhibits the project of rethinking notions of form. (582)

Greater attention to mathematics does not necessarily mean losing a focus on linguistic models; indeed, modern research on language and modern research on maths share common roots in the 19th century. Woolf's novels explore similarities between mathematical and literary language and also refer to developments in maths, such as an increasing focus on form, self-referentiality, and a loss of some of its traditional certainty. The following outline of developments in 19th-century mathematics, and of literary engagements with these, will lay the basis for the analyses of *Night and Day* and *To the Lighthouse*.

When not writing literature under the pen name 'Lewis Carroll,' Charles Dodgson worked on mathematical logic at the University of Oxford, and his mathematical interests inform his well-known *Alice in Wonderland* (1865) and *Through the Looking-Glass* (1871). Discussing some quotations from these texts can illuminate how decisive developments in maths travelled outside the scientific sphere. In particular, Carroll's texts reflect a sense of loss of certainty that mathematicians experienced and an increasing focus on form. After going down the rabbit hole into unfamiliar surroundings, Alice attempts to gain confidence by recalling what she used to know. That Alice first turns to mathematics in her epistemological crisis suggests its privileged position in Victorian culture:

> I'll try if I know all the things I used to know. Let me see: four times five is twelve, and four times six is thirteen, and four times seven is – oh dear! I shall never get to twenty at that rate! However, the Multiplication-Table doesn't signify: let's try Geography. (Carroll 2010, 9)

Mathematics fails to ground knowledge, Alice no longer experiences it as useful, and readers might question its correctness. Yet, while Alice's calculations are erroneous in the most commonly used number system based on 10, her multiplications are correct when using non-decimal based number systems (see Bilban 2015, 324). That the correctness of calculations depends on which number system is used highlights the fact that arithmetic is based on conventions rather than natural knowledge. Consequently, as Alice notices, the multiplication table does not 'signify:' it does not have any particular referents or meaning in reality but encompasses different systems and diverse applications.

Alice's experience of the arbitrariness of mathematics, and her consequent abandonment of trying to use it to determine the grounds of knowledge, mirror Carroll's/Dodgson's struggles with 19th-century developments in symbolic algebra. Decisively shaped by George Peacock and Augustus De Morgan, symbolic algebra is based on the conception of algebra as a purely formal, symbolic language and the irrelevance of the nature of its objects. This allowed including contested objects, such as negative and imaginary numbers: in symbolic algebra, the meaning or (missing) referent of numbers is irrelevant but the focus is on relations and operations between abstract objects. Peacock described algebra as "*the science which treats of the combinations of arbitrary signs and symbols by means of defined though arbitrary laws*" (1830, 71; original emphasis), and De Morgan explained: "no word nor sign of arithmetic or algebra has one atom of meaning throughout this chapter, the object of which is *symbols, and their laws of combination*, giving a *symbolic algebra*" (1849, 101; original emphasis). As these quotations show, symbolic algebra is indicative of a new focus on form when it takes maths not to directly represent physical reality but to be concerned with its own symbols and the abstract structures they form.

Considering the difference from the empirical natural sciences, whose object of enquiry is physical reality, mathematics – along with logic, theoretical computer science, and theoretical linguistics – is classified as a formal science. While examinations of form did, of course, not begin with symbolic algebra and the closely related mathematical logic, the 19th century saw rapidly increasing attention to formal aspects: "Formalism had been important to earlier varieties of logic, […] but in the mathematical logic of the nineteenth century it was 'erected into a general principle'" (Bochenski 1961, 266 qtd. in Henderson 2018, 69). In 1902, Henri Poincaré declared: "Mathematicians study not objects, but relations between objects; the replacement of these objects by others is therefore indifferent to them, provided the relations do not change. The matter is for them unimportant, the form alone interests them" (2015, 44). As formalist maths focuses on form rather than the empirical reality or meaning of objects, ideas of mathematical truth and certainty change: mathematical knowledge no longer concerns the interpretation of symbols but the relations between them.

"Dodgson seems never to have accepted the new algebra," Helena Pycior concludes in her study on its role in Carroll's work: "The *Alices* embodied the mathematician Dodgson's misgivings about symbolical algebra," not least his "anxiety over the loss of certainty implicit in mathematicians' acceptance of the symbolical approach" (1984, 160; 149; 170; original emphasis). An example from *Through the Looking-Glass* illustrates how Carroll not only responds to a sense of loss of certainty that induces Alice to abandon seeking reassurance in mathematical knowledge but also to the increasingly close relations between maths and language at the time, and the possibility of multiple interpretations that a focus on form opened up in both areas. In *Through the Looking-Glass*, Alice again encounters the idea that signs are arbitrary:

> "When *I* use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean – neither more nor less."
> "The question is," said Alice, "whether you *can* make words mean so many different things." (Carroll 2010, 57; original emphasis)

This brief exchange might remind a literary scholar of Ferdinand de Saussure's insight into the arbitrariness of signs and his structuralist notion of language. Saussure would agree that if Humpty Dumpty defines the word 'cat' to mean what is normally referred to as 'table,' there is nothing in language itself to suggest that 'cat' more properly denotes an animal that catches mice (as Alice notices, there remains the question of how successful such definitions are).[2] According to Saussure, signs gain meaning not in reference to reality but in relation to other signs. In other words, Saussure understands language as a structure of relations – as "*a form and not a substance*" (2011, 122; original emphasis). Similarly arguing for the arbitrariness of words and implying a shared structure between mathematical and everyday language, David Hilbert, probably the most famous mathematician of the early 20th century, states: "It must be possible to replace in all geometric statements the words *point*, *line*, *plane*, by *table*, *chair*, *mug*" (qtd. in Reid 1970, 264, original emphasis). Hilbert here denies that the concepts of point and line have any intrinsic or intuitive meaning: Rather than following a tradition since Euclid that bases geometry on supposedly self-evident truths derived from experience and intuition of space, Hilbert views it as independent of meaning and reference to physical reality. As mathematician and philosopher Gottlob Frege wrote to him: "It seems to me that you want to divorce geometry completely from our intuition of space and make it a purely logical discipline, like arithmetic" (Frege 1971, 14). Indeed, Hilbert held that any scientific subject should be developed without recourse to intuition.

Frege, who in the 19th century established the mathematical school of logicism as well as the basis for a modern philosophy of language, is at the basis of Hilbert's considering mathematics in terms of language and *vice versa*. Frege's attempts to develop an ideal, unambiguous language based on maths fed into the rise of analytic philosophy, whose practitioners, such as Bertrand Russell and G.E. Moore, employ the formalism and symbolism of mathematics for research into the logical structure of talking and gaining knowledge about the world. Yet already in 1835, De Morgan considers that concentrating on mathematical symbols and form might threaten the clarity of meaning, wondering

> whether it might not be possible so to vary the meaning of the signs, as to make an entirely different algebra, which should nevertheless present exactly the same theorems in form as the old one, the forms having different meanings. [...] This may seem something like

2 For a discussion of the role of mathematics for structuralist Roman Jakobson's work, see Cassidy (1900, 143-144). For discussions of the relation between structure and form, see Rogers (2014, 8-9).

> asking, whether two different languages might have all their words in common, but with different meanings, in such manner that by writing a treatise on astronomy in the first language, we write, *totidem verbis*, a treatise on music in the second. (1835, 104-105; original emphasis)

The above quotations by mathematicians and Carroll's literary characters demonstrate awareness in the 19th and the early 20th century that mathematics and everyday language share similar structures, comparable arbitrariness of their signs, and, consequently, the possibility of multiple interpretations. It is against the background of these developments that Woolf turns to maths to explore ideas of knowledge, form, and literary innovation.

If, as Andrea Henderson shows in her work on mathematical formalisms and Victorian culture, "[n]ineteenth-century mathematicians were very aware that in distinguishing content from form and privileging the latter they were fundamentally changing their discipline and its claims upon truth" (2018, 30; see also Henderson 2014), the same could be said about Woolf: reflecting on mathematical questions of content, form, and knowledge, her work draws conclusions for literary writing and the knowledge and truth it creates. In what follows, this paper examines how Woolf's *Night and Day* and *To the Lighthouse* respectively engage with mathematics and discussions about it, both in the contents and forms of the novels. As the main protagonist in *Night and Day* works on maths, it is part of the content level, while its role in *To the Lighthouse* is less obvious. Yet, regarding the latter, considering the formalist notion of maths helps us to better understand Woolf's formalist aesthetics and her idea of the epistemological potential of form. It is worth pointing out here that the term 'formalism' was used in the field of mathematics before it emerged in art and literary criticism (see cf. Rodal 2018, 94), and Woolf draws on these mathematical roots in her formalist fiction. As we shall see, she uses maths as a source of ideas about form, but also, importantly, as a method of gaining knowledge through focusing on form.

1. Virginia Woolf, *Night and Day* (1919)

Not unlike Humpty Dumpty in the quotation above, Virginia Woolf stresses the changing and multiple meanings of words. In the 1937 broadcast and essay "Craftsmanship," she explains:

> it is their [words'] nature not to express one simple statement but a thousand possibilities […]. [T]hey hate anything that stamps them with one meaning or confines them to one attitude, for it is their nature to change. Perhaps that is their most striking peculiarity – their need of change. It is because the truth they try to catch is many-sided, and they convey it by being themselves many-sided, flashing this way, then that. (Woolf 2008, 86; 90)

Woolf calls for a literature that does justice to this many-sidedness of words and truth. The role that mathematics plays in answering this demand is most immediately evident in *Night and Day* (hereafter quoted as ND), Woolf's second novel, with its maths-loving main protagonist Katharine Hilbery. As the title suggests, the novel sets up a number of oppositions and then challenges them: night and day, male and female, individual feeling and social façade, and, not least, mathematics and literature. Compared to Woolf's later novels, *Night and Day* has received little critical attention, and early readers were divided in opinion, some criticising it as old-fashioned and ignoring current events. Katherine Mansfield likened the novel to "a ship that was unaware of what has been happening" (qtd. in Froula, Kimber, and Martin 2018, 150) and in a letter from 1919 called it "a lie in the soul […] [W]e have to take it [the First World War] into account and find new expressions, new moulds for our new thoughts and feelings" (qtd. in Goldman 1993, 102). Veering between contrasted poles, not least between Victorian tradition and a new, modern age, *Night and Day* is not stamped with one meaning but, in Woolf's own words, testament to "the process of discarding the old, when one is by no means certain what to put in their place" (Woolf 2003, 10). Mathematics is one way in which the novel illustrates the struggle, not to define new content, but to create openness for the possibility of the new.

In *Night and Day*, mathematics does not contribute to what Woolf would later describe as the urge to stamp words – and people – with 'one meaning' and prevent them from changing. Katharine Hilbery, born into a literary family, helps her mother to prepare a biography of Katharine's grandfather, a famous poet. Where her mother aims to capture the poet's life in a book, Katharine feels that the attempt is futile, and she herself loathes being defined by words. To escape being limited by language and social conventions, Katharine turns to maths: "upstairs, alone in her room, she rose early in the morning or sat up late at night to […] work at mathematics" (ND, 37). Readers might expect her to cherish maths for its rigour, its certainty, its perfect knowledge. However, in an imagined conversation with her cousin, Katharine explains:

> I don't care much whether I ever get to know anything – but I want to work out something in figures – something that hasn't got to do with human beings. […] And if I could calculate things, […] and have to work out figures, and know to a fraction where I was wrong, I should be perfectly happy. (ND, 183)

This explanation of Katharine's motivation seems to sever the traditional tie between mathematics and certain knowledge: Katharine does not care whether she gets to "know anything" (ND, 183). Yet, while her choice of words implies that maths does not constitute knowledge, a more accurate description would be that it does not have meaning in the world, but that mathematical knowledge emerges on a different level: the level of form, or rather, of working on form – forming. That is, Katharine describes maths as an activity, not as a result: it means "working out," working towards something but not necessarily arriving at knowledge beyond maths itself. The forming work Katharine engages in is not arbitrary – she knows she can be "wrong" (ND, 183) and that results are precise – and the insights she gains differ from traditional knowledge when they concern relations between symbols rather than their interpretation. This mathematical or formal knowledge, which Katharine does not count as 'knowledge proper,' thus does not involve stamping figures with one meaning but exploring possible forms of relations.

Woolf's novel underlines these characteristics of 'formal knowledge' when it does not refer to any particular mathematical content; instead, maths features as writing. For example, when Katharine takes a walk with her future husband Ralph Denham, she is distracted not by any specific mathematical problem but by the form of mathematical writing: "If Denham could have seen how visibly books of algebraic symbols, pages all speckled with dots and dashes and twisted bars came before her eyes as they trod the Embankment, his secret joy in her attention might have been dispersed" (ND, 287). Similarly, when her mother and aunt exchange family news, Katharine "cast her mind […] towards pages of neatly written mathematical signs" (ND, 204). In other words, it is the writing, the visible form of maths, rather than any content that fascinates Katharine. These examples also show that maths takes Katharine away from ordinary life, her lover, and family concerns. Thus, while her mother aims to use writing to cast her grandfather's life into a fixed form, Katharine's mathematical writing removes her from concern with knowledge of human beings and the world.[3] Katharine accordingly experiences mathematics as a realm of freedom: through it, she can escape the societal conventions of 'ordinary life' and avoid becoming defined by the content of words. Literary scholar Ann-Marie Priest stresses the difference between everyday language, which is a tool of society and particularly of patriarchal power, and mathematical writing:

> Katharine's algebraic squiggles represent her precisely by not representing her. They convey nothing whatever about her – and thus they do not constrain, construct, or delimit her in any way. Thus, she can accept them – as symbols which simply create a textual space for her, without giving that space any content. (2003, 71)

When asking what mathematical form 'knows' about Katharine in *Night and Day*, the answer is: nothing. And this is, precisely, its attraction. Thus, if Katharine enjoys manipulating mathematical symbols that do not intrinsically hold but can potentially be filled with meaning, the activity allows her to enjoy similar indeterminacy and potentiality. In other words, the content of her work mirrors the form that her mathematical activity takes: Both create possibilities without actualising them.

Mathematics in *Night and Day* – standing for absence of content and meaning, for written symbols without referents, and for not static knowledge but activity – corresponds to the formalist notion of maths. As developed above, formalist mathematics has its roots in the 19th century, but it continued to be widely debated in the 1910s and 1920s, not least by members and associates of the Bloomsbury Group (see also below). The name most closely related with formalist maths, and with early 20th-century mathematics more generally, is David Hilbert, and Hilbert's presence haunts *Night and Day*: only one letter distinguishes his last name from Katharine Hilbery's, and through Katharine's thinking, the novel introduces the formalist notion of maths that Hilbert promoted. He advocates a concentration on its arbitrary signs, bracketing questions of content in order to focus on form:

> the objects [Gegenstände] of number theory are for me […] the signs themselves […]. [T]he usual contentual [inhaltlich] ideas of the mathematical theory must be replaced by formulae and rules […]. [T]he contentual thoughts (which of course we can never wholly do without or eliminate) are removed elsewhere – to a higher plane, as it were […]. The solid philosophical attitude that I think is required for the grounding of pure mathematics

3 See Reed (1992) for a discussion of Woolf's critique of purely aesthetic values, as well as of different stages in her formalism and its relation to feminism.

> – as well as for all scientific thought, understanding, and communication – is this: *In the beginning was the sign.* (Hilbert 2005, 1121; 1123; 1123-4; 1122; original emphasis)[4]

With his focus on mathematical signs, Hilbert wants to bracket its content so that important work on the structure can be done and formal knowledge be gained. As the quotation shows, Hilbert does not claim that maths has no content or meaning in the world but argues that a concentration on signs is needed to establish the foundations, and therefore the certitude of maths. So both David Hilbert and Katharine Hilbery treat mathematics as a formal, self-referential language, the symbols of which have potential but not fixed content or meaning outside the system itself. They both value the openness resulting from this self-referentiality, as mathematical work does not narrow down meaning in concrete applications but extends formal possibilities – the affordances of form – without resulting in arbitrariness: Katharine praises maths for the possibility to "know to a fraction where [one] was wrong" (ND, 183), and Hilbert takes the concentration on form to be a prerequisite for ensuring the certainty of any mathematical and scientific knowledge. The knowledge formalist maths leads to is thus understood to be certain, yet to constitute knowledge of possibility rather than of reality.

That the meaning of symbols or words is undetermined reminds us of Humpty Dumpty's conversation with Alice as well as Woolf's "Craftsmanship," and Katharine also explicitly contemplates the idea and the ensuing room for multiple, changing meanings in *Night and Day*:

> Much depended, as usual, upon the interpretation of the word love: which word came up again and again, whether she considered Rodney, Denham, Mary Datchet, or herself; and in each case it seemed to stand for something different, and yet for something unmistakable and something not to be passed by. (ND, 300)

In the novel, mathematics exemplifies the openness and variability of words that Katharine senses but that conventional use suppresses, when it is focused not on content but on form. Apart from working as a model for a new language, maths in its formalist understanding serves Woolf to present what she calls "the process of discarding the old, when one is by no means certain what to put in their place" (2003, 10): like formalist maths, the novel discards what traditionally counted as meaning yet does not replace it with anything new – it 'brackets' meaning to create new formal possibilities. However, the formalism that *Night and Day* develops in reference to maths hardly translates to its own novelistic form. While some scholars notice beginnings of Woolf's modernist technique (Outka 2016; Quigley 2008), this early novel remains fairly close to the

4 Es "sind mir […] die Gegenstände der Zahlentheorie die Zeichen selbst […]. Dazu müssen aber zunächst die üblichen inhaltlichen Überlegungen der mathematischen Theorie durch Formeln und Regeln ersetzt bzw. durch Formalismen nachgebildet werden […]. [D]adurch werden die inhaltlichen Überlegungen, die selbstverständlich niemals völlig entbehrt oder ausgeschaltet werden können, an eine andere Stelle, gewissermaßen auf ein höheres Niveau verlegt […]. Hierin liegt die feste philosophische Einstellung, die ich zur Begründung der reinen Mathematik – wie überhaupt zu allem wissenschaftlichen Denken, Verstehen und Mitteilen – für erforderlich halte: *am Anfang* – so heißt es hier – *ist das Zeichen*" (Hilbert 1935 [1922], 163; 165; original emphasis).

conventions of 19th-century realism. It is Woolf's later novel *To the Lighthouse* that explores the role of formalist mathematics for literature through its own form.

2. Virginia Woolf, *To the Lighthouse* (1927)

In *To the Lighthouse* (hereafter quoted as TL), too, a single letter distinguishes the protagonists, the Ramsay family, from a mathematical double: Frank Ramsey was a member of the Cambridge Apostles, many of whom went on to form the Bloomsbury group, and Virginia Woolf knew him personally.[5] The remark in the novel that Mrs. Ramsay is unable to follow talk about the university and a fellow's "Prolegomena, of which Mr. Tansley had the first pages in proof with him if Mr. Ramsay would like to see them, to some branch of mathematics or philosophy" (TL, 11) refers to the close relationship between maths and philosophy in Ramsey's work and analytic philosophy at the time. In Britain, analytic philosophy, with its roots in symbolic algebra and Frege's logicism, was first of all associated with Bertrand Russell, who greatly influenced the Bloomsbury Group. As Michael Whitworth points out, "[i]n contextualizing Woolf's work, there is a danger of assimilating her to a 'Bloomsbury' with which she was not always sympathetic" (2005, 130; see also Reed 1992). Nevertheless, briefly considering the work of Bloomsbury members Clive Bell and Roger Fry can illuminate the role of maths for various expressions of formalist thinking and point to the specificity of Woolf's engagement with it in *To the Lighthouse*.

Ann Banfield examines in detail how Russell's analytic philosophy found reception in the philosophical and aesthetic formalism of Bloomsbury:

> The nature of the response to mathematization and logical formalism in modern art is quite varied. But one obvious place to begin exploring the operation of its influences is where it is most documentable, as is the case for the activity of Bloomsbury artists and writers. (2006, xii)

Roger Fry and Clive Bell introduced formalist conceptualisations of art, particularly in reference to painting, for example maintaining that the use of formal elements – of line, colour, and shape – is significant in itself. Both refer to mathematics in their works: Fry compares the response to mental constructions in pure maths to aesthetic appreciation, and Bell similarly proposes a close relation between "appreciators of art and of mathematical solutions" as both feel a removal from "the world of man's activity" to a state of exaltation (Miller 1988, 58). While in Wonderland Alice learns that "the Multiplication-Table doesn't signify" (Carroll 2010, 9), neither Bell nor Fry lose sight of the significance of forms and formal systems in the real world. For example, while Bell stresses the importance of formal and technical aspects of painting, he also retains a view to its meaning and emotional impact: the term he coined, "Significant Form" (Bell 1920, 8), combines attention to form as well as to significance or meaning. When revisiting an apparent incompatibility between formalism and significance similarly noted by Carroll/Dodgson half a century earlier, Bell and Fry also consider mathematics, and Banfield suggests that "Woolf, untrained in logic, mathematics and philosophy" encounters ideas from these fields through Fry's theory of art: "it is Roger

5 Ann Banfield points out Frank Ramsey as a possible source for Ramsay's name (2006, 404).

Fry's theory of Post-Impressionism that provides the crucial link between the logical [and mathematical] underpinnings of Cambridge theory of knowledge and her theory of 'modern fiction'" (Banfield 2006, x). Fry's contact with Russell and other members of the Cambridge Apostles meant that he was "uniquely situated to recognize and theorize Cézanne's [and other Post-Impressionist painters'] response to the formalism which was beginning to define modern thought" (Banfield 2006, xi). While the importance of Fry's and Bell's aesthetic formalism for depictions of painting in Woolf's work and for her aesthetic theory has long been recognised, particularly regarding *To the Lighthouse* with its artist character Lily Briscoe (McLaurin 1973; Roberts 1946; Torgovnick 1985), Woolf's reception of mathematical ideas might be less tied to Fry's work than Banfield suggests. Indeed, Woolf's wider circle included, next to Ramsey and Russell, mathematicians G.H. Hardy and Alfred North Whitehead and thus also allowed for more direct forms of exchange.[6] Acknowledging the wider intellectual context in which mathematical ideas were disseminated, yet bracketing questions of influence, I now turn to examining Woolf's engagement with maths in *To the Lighthouse* and the insights this yields into her experimentation with literary formalism.

In contrast to *Night and Day* where Katharine experiences maths as being outside of patriarchal power structures, in *To the Lighthouse* the discipline is tied to ideas of patriarchal domination. Mrs. Ramsay feels excluded from a mathematical discussion at the dinner table, wondering what

> her husband was saying about the square root of one thousand two hundred and fifty-three, which happened to be the number on his railway ticket. What did it all mean? To this day she had no notion. A square root? What was that? Her sons knew. She leant on them; on cubes and square roots; […] she let it uphold her and sustain her, this admirable fabric of the masculine intelligence. (TL, 115)[7]

Yet, maths also features more positively in the novel, not as an institutionalised discipline but in the abstract mathematical form in Lily Briscoe's painting: the purple triangle stands for Mrs. Ramsay and her son James, but it is not supposed to realistically represent them; instead Lily aims to get at a truth beyond appearance. To do so, she focuses on geometrical form, such as the triangle, and on "relations of masses, of light and shadows" (TL, 59). As has been often discussed, Lily Briscoe's painting serves to establish the formalist aesthetics of the novel: attention to formal properties and to relations is evident in the construction of *To the Lighthouse*, not least in its tripartite structure of two sections concerned with journeys to the lighthouse and the middle section, "Time Passes," addressing abstract, impersonal change: it "is a novel about how an artist struggles to achieve (a modernist and a painterly) form, while at the same

6 Jocelyn Rodal lists sources for Woolf's relations with mathematicians, including Russell, Ramsey, Hardy, and Whitehead (2018, 75).

7 According to Quentin Bell, Woolf's nephew, "Virginia continued throughout her life to count on her fingers" (1972, 26) while her brother Thoby pleased their father by showing some mathematical abilities. Woolf partly based Mr. Ramsay on her father Leslie Stephen, and Andrew Ramsay, the oldest child who "should have been a great mathematician" (TL, 210) shares some characteristics with her brother Thoby.

time actually embodying that form" (Briggs 2006, 103). As we shall see, mathematics provides Woolf with another means to self-reflexively draw attention to its manner of composition: Employed at the level of content as well as at the level of form, maths exemplifies how formal exploration itself becomes content in the novel.

As in *Night and Day*, in *To the Lighthouse* mathematics stands not for concrete knowledge but is an example of a method of relating to objects. When painting, Lily Briscoe does not seek knowledge of her object, Mrs. Ramsay, but strives for unity: "Could loving, as people called it, make her and Mrs. Ramsay one? for it was not knowledge but unity that she desired" (TL, 57). And Lily describes the love she bears her 'objects' in mathematical terms: it is "love that never attempted to clutch its object; but, like the love which mathematicians bear their symbols, or poets their phrases, was meant to be spread over the world" (TL, 53). Here, maths and literary writing are presented as sharing characteristics of openness, and of not tying down their objects to determinate meaning. Such mathematical or literary writing does not convey any specific knowledge then, but it is a form of abstract, general knowledge of change and openness and of unity in love.

Jane Goldman and other scholars see these characteristics reflected in the novel's title, too: The title is not a static, precise "The Lighthouse," but "*To* the Lighthouse," which carries implications of indeterminacy, of openness, of "working towards" something (Goldman 2015, 32). Similarly undetermined is the symbolism in the novel. When Roger Fry wrote in a letter that "arriving at the Lighthouse has a symbolic meaning which escapes me" (qtd. in Woolf 1977, 385), Woolf famously answered:

> I meant *nothing* by The Lighthouse […]. I saw that all sorts of feelings would accrue to this, but I refused to think them out, and trusted that people would make it the deposit for their own emotions – which they have done, one thinking it means one thing another another. I can't manage Symbolism except in this vague, generalised way. (1977, 385; original emphasis)

Woolf's explanation corresponds to the description of mathematical symbols in *Night and Day*: in both cases, symbols are abstract, ungraspable, and changing as readers continuously 'work out' their meanings. Loath to stamp them with one meaning, Woolf uses symbols with an understanding comparable to Katharine's, and also Hilbert's, in their manipulations of mathematical writing: Both literary and mathematical symbols do not intrinsically hold but can potentially be filled with meaning. Knowledge derived from the novel's symbolism does not consist in any specific interpretation then, but the novel's drawing attention to the abstract form of symbols leads to the 'vague, generalised' knowledge that form allows for multiple possibilities. The form of symbolic knowledge – that is, knowledge obtained by means of symbols, both in mathematics and in *To the Lighthouse* – is emptied of specific content but work on the form and its possibilities itself become the subject matter.

If Fry wonders whether it matters that meaning escapes him, Katharine Hilbery is clear on that score: she does not "care much whether [she] ever get[s] to know anything" (ND, 183). While not out to gain specific information, Katharine achieves the 'formal knowledge' that seems to elude Fry: the vague, unspecific knowledge of possibilities rather than reality. Similarly, in "Craftsmanship," Woolf not only accepts but also celebrates the "thousand possibilities" that words express (2008, 86). The feeling that words need to be liberated and to change, and are connected to the situation of maths, echoes in *To the Lighthouse*. "Words [that] fluttered sideways and struck the object inches too low" (TL, 193) do not represent reality directly, and Lily Briscoe uses mathematical vocabulary when questioning the possibility of value and meaning: "How did one add up this and that and conclude that it was liking one felt, or disliking? And to those words, what meaning attached, after all?" (TL, 29). As neither mathematical summation nor everyday language lead to clear results, they cannot supply certain knowledge and truth but create space for a "thousand possibilities" of meaning.

In a pioneering paper, Jocelyn Rodal argues that central symbols in Woolf's novels "share the semantic properties of mathematical variables: markers that are designed to flexibly denote multifarious, undetermined meanings" (2018, 73). As Rodal develops with reference to work by Shankar Raman, mathematical variables such as x are not only placeholders for a specific solution (as in $2x = 6$, where $x = 3$) but can also indicate that many meanings are possible: in the expression $ax = b$, for example, x can take on various different values (Rodal 2018, 88). As Raman explains: introducing mathematical variables initiates "a shift from representing things – be they commodities, people, or algebraic unknowns – as determinate-but-unknown to representing them in their merely potential determinateness" (2010, 213). Denoting not randomness but multiple possibilities, mathematical variables offer Rodal "a uniquely descriptive model by which we can understand the multiplicities, ambiguities, and contradictions of Woolf's symbolism" (2018, 77), which she tests focusing on *Jacob's Room* and *The Waves*.

As Rodal grasps in the model of mathematical variables and Woolf explains herself in her response to Fry, her works offer knowledge only in the "vague, generalised way" (Woolf 1977, 385) of symbolism allowing for various interpretations: her symbols do not convey concrete knowledge but open up a (formal) space in which meaning becomes possible but is not actualised – meaning remains bracketed. The most experimental middle section of *To the Lighthouse*, entitled "Time Passes," literally brackets the personal and specific to focus on abstract change and the general passing of time: the deaths of Mrs. Ramsay and her children Andrew and Prue all appear in square brackets. We might see these formal, un-poetic brackets as some form of "twisted bars" (ND, 287) in mathematical writing that Katharine sees before her inner eye in *Night and Day*, and they function in a similar way as Katharine Hilbery and David Hilbert propose formalist maths to work: to bracket specific content in order to concentrate on form, to the point where preoccupation with changing form itself becomes the content. As Goldman suggests, mathematics might therefore be considered a more important inspiration for Woolf than painting: the novel's "triadic design, […] its carefully numbered subsections, its idiosyncratic deployment of square and round brackets, may be rooted in science, mathematics, or logical philosophy rather than in painting" (2015, 34). Indeed, maths in its formalist incarnation allows Woolf to emphasise a level of abstraction and self-reflexivity that painting does not quite reach: the purple triangle in Lily Briscoe's painting stands for Mrs. Dalloway and her relations – even if it does not represent her directly, it has a definitive meaning and relation to reality. Mathematics – the abstract form of the triangle rather than its visual representation in purple – does not have this tie and is thus better suited to Woolf's claim that she "meant *nothing* by The Lighthouse" but for it to encompass diverse possibilities.

To the Lighthouse draws on mathematics as a topic and in its writing style, including the use of technical symbols such as brackets, and it thus intensifies the idea that focus on form suspends specific meaning to allow for multiple possibilities to develop. As for Hilbert, Woolf's privileging of abstraction and form does not preclude so much as bracket reference. Possibilities for meaning remain, and the focus on this potentiality distinguishes Woolf's formalism from celebrations of a purely aesthetic realm without reference to reality: What always has to be borne in mind is the formal knowledge of the arbitrariness of symbols – be they mathematical, linguistic, or literary – but also the multiplicity of potential meanings. Since maths encompasses these characteristics, I agree with Goldman that the importance of maths for Woolf's formalist experimentation has to be acknowledged and examined apart from its reception through Fry's aesthetic theory of art. Not least, Woolf uses formalist maths as a model of a method – that is, as an example of formalist activity leading to knowledge of possibility and multiplicity.

Conclusion

To come back to the beginning:

> "When *I* use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean – neither more nor less."
> "The question is," said Alice, "whether you *can* make words mean so many different things." (Carroll 2010, 57; original emphasis)

In texts by Woolf, mathematics helps characters and readers see that signs are arbitrary and do not privilege a specific meaning or 'truth,' and that words, symbols, and novels can mean many different things.[8] *Night and Day* primarily addresses maths in its content, as a formal, symbolic language that is impersonal, does not represent the physical world, and does not delimit its objects or users. Although the form of the novel remains largely traditional, maths does work as a formal model when it allows Katharine to experiment with what Woolf claims the novel to present, namely "the process of discarding the old, when one is by no means certain what to put in their place" (2003, 10). This does not imply the impossibility of meaning or the complete detachment of aesthetics from reality but describes the need to bracket content and work on creating new possibilities for it. In *To the Lighthouse*, the 'free love' that formalist mathematicians bear their symbols by bracketing specific content, is more evident in the novelistic form: the novel's symbols, such as the lighthouse, are undetermined, shifting, and allow for multiple meanings. The formal science of mathematics thus serves to develop Woolf's

8 Woolf's work demonstrates continuities between a Victorian engagement with mathematics, for example Carroll's writing, and modernist experimentation. Woolf's and Carroll's similar concerns with modern mathematics' focus on form, its independence from reality, and close relation to language, indicate that "the formalist impulse of [… Victorian] algebraic art was a crucial precursor to a set of similar tendencies in early modernism" (Henderson 2018, 192).

novelistic forms. Importantly, however, maths primarily exemplifies a method of gaining knowledge – vague, shifting knowledge – in her work. In other words, maths in Woolf's novels epitomises not form – not static triangles, purple or otherwise – but formalism, the activity of 'working things out' by focusing on form.

When in *Night and Day* and *To the Lighthouse*, the formal science of mathematics does not constitute or convey concrete knowledge but rather exemplifies a method of relating to objects, it confirms Angela Leighton's conception of form as "a way of knowing, not as an object of knowledge" (2007, 27) and also Turner's notion that form includes an active quality: he argues that form "should be understood as a verb rather than a noun" (2010, 582). As formalist mathematics and Woolf's novels suggest, the shaping principle of form does not need to result in determinate being but can also convey "vague, generalised" (Woolf 1977, 385) possibilities and "merely potential determinateness" (Raman 2010, 213). It is not least in this potentiality that modern mathematics and modernist literature connect: both explore forms of possibility, partly apart from the pressures of reality. Woolf's works draw on this common feature when taking the formal knowledge that maths relays to suggest that form conveys "a more profound knowledge than an empirically oriented mimesis could provide" (Henderson 2018, 30). If modern maths and literature share characteristics when focusing on form and reveal the multiplicity of all meaning, importantly, the "many different things" their respective symbols can mean are not arbitrary but determined by the integrity and the affordances of the system. Engaging in mathematical and literary activities then is to extend these affordances by working on form, and it is in this respect that Woolf's work proposes intersections between mathematical and literary ways of knowing and confirms the fruitfulness of turning to maths when studying literary form.

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