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Narrative Positioning

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Abstract

This paper introduces philosophers of engineering to a new research agenda currently permeating the history and philosophy of science, one concerned with the functions of narrative in science. It draws on two ideas from literary studies (tellability and focalisation) and one from the philosophy of history (synoptic judgment) in order to build a new concept, narrative positioning, which captures some of the important (though often overlooked) ways in which narrative is present in the making of research programmes, designing experiments, and the assessment of results in science and engineering.

1. Introduction

This paper introduces philosophers of engineering to a new research agenda currently permeating the history and philosophy of science, one concerned with the functions of narrative in science.[1] Thus far, scholars addressing narrative science have, as the name suggests, primarily focussed on the sciences, rarely touching on technological or engineering cases. There are however very clear ways in which the narrative science research agenda can be extended into the world of

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* I would first like to thank the research team of the Dandelion project for access to their early meetings. In this respect, my very considerable thanks to Dr Cathal Cummins and Dr Madeleine Seale, two postdoctoral researchers on that project who gave numerous hours of their time to discussing their research with me, and provided excellent feedback on this paper. Next I must thank the Engineering Life project, which directed me towards the themes of biological engineering and funded the 2 years of empirical research from which this paper emerged. As such this research was supported by the European Research Council through Consolidator Grant (616510-ENLIFE). Since then I have joined the Narrative Science project, and received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 694732), which directly informed my analysis. The team of researchers, Mary S. Morgan, Sabine Baier, Robert Meunier, Kim Hajek, Mat Paskins, Andrew Hopkins, and our international collaborator, M. Norton-Wise, all helped improve it greatly. Last then, my thanks to the attendees at fPET in Maryland, and the organisers Zach Pirtle, Guru Madhavan and David Tomblin. Special thanks to Mary S. Morgan for providing much-needed feedback on this working paper.

[1] Morgan, Mary S. and M. Norton Wise. 2017. Narrative science and narrative knowing. Introduction to special issue on narrative science. *Studies in History and Philosophy of Science* 62:1-5. For more on the project please visit the Narrative Science website www.narrative-science.org [last accessed 19/12/2018].

engineering, and to their mutual benefit. Here I deliver one example, that of the importance of 'narrative positioning' for engineering researchers, which in my case happens to arise thanks to a collaboration between engineers and biologists.[2]

Some researchers in engineering studies and the philosophy of engineering already take narrative seriously, but this work has typically focussed on the importance of narrative for pedagogy and identity.[3] Narrative here is not treated so much as a way of knowing, but rather as a medium for explanation and representation.[4] Louis Bucciarelli does make repeated reference to the importance of narrative in his *Engineering Philosophy*, but what narrative is taken to mean is not developed, and again his examples often lean towards teaching.[5] Pedagogy and identity are clearly very important, and there is no need to view them in isolation of research, experimentation, and everything else that makes up engineering. For example, in a recent seminar series dedicated to narrative science Caitlin Donahue Wylie argued that engineering educators make use of narratives, particularly failure narratives, to acclimatise their students to some of the realities of engineering in the world, all the while building particular kinds of engineering identity.[6] Through Wylie's example, we can immediately acknowledge that pedagogy matters, that there is more to pedagogy than pedagogy, and

[2] My attention to interdisciplinary projects between biology and engineering was inspired by the Engineering Life project, which sponsored the empirical research analysed here. Schyfter, Pablo, Emma Frow and Jane Calvert. 2013. *Engineering Studies*. 5:1-5. For more on the project please visit the Engineering Life website http://www.stis.ed.ac.uk/engineeringlife/home [last accessed 19/12/2018].

[3] One important exception is Bill Wimsatt who includes a section on 'Narrative accounts and theory as Montage' in his *Re-engineering Philosophy for Limited Beings* (2007). This will be built on later.

[4] Buch, Anders and Louis L. Bucciarelli. 2015. Getting context back in engineering education. In *International Perspectives on Engineering Education*, eds. Christensen, Steen Hyldgaard, Christelle Didier, Andrew Jamison, Martin Meganck, Carl Mitcham, and Byron Newberry. Cham: Springer. Downey, Gary Lee. 2008. The Engineering Cultures syllabus as formation narrative: Critical participation in engineering education through problem definition. *St. Thomas Law journal* 5:101-130. Korte, Russell. 2013. The Formulation of Engineering Identities: Storytelling as Philosophical Inquiry. In *Philosophy and Engineering: Reflections on Practice, Principles and Process*, eds. Michelfelder Diane p., Natasha McCarthy and David Goldberg. Dordrecht: Springer. Philosophy of Engineering and Technology, vol 15.

[5] Bucciarelli, Louis L. 2003. *Engineering Philosophy*. Delft: Delft University Press.

[6] Wylie is currently preparing an article on disaster stories for publication, a version of the vicarious learning work is published as Wylie, Caitlin Donahue and Michael E. Gorman. 2018. Learning in Laboratories: How Undergraduates Participate in Engineering Research. American Society for Engineering Education. Paper ID #22448.

likewise, that narrative has a much broader epistemic significance. In turn, my conclusions may well repay scholars attending to pedagogy, more specifically with respect to Wylie's concept of 'vicarious learning', which helped shape my own thoughts.

Aspects of making new engineering knowledge covered by this paper include: the collection of candidate starting points; the design of experiments; and modes of judgement or interpretation of evidence. At each step narrative plays an essential role either as a way of knowing or an epistemic tool. These elements are gathered together under the umbrella function of 'narrative positioning' which is a fundamentally epistemic activity rather than a particularly discursive or rhetorical one. Narrative positioning is also in some senses similar to 'framing', which concerns the ways in which agendas, decisions, and outcomes are packaged or put together for the consumption of, or the influencing of, broader audiences.[7] The majority of studies concerned with framing do not however reach into experimentation, instead focussing on communication between science, policy, publics, industry, and so on. In contrast to framing, narrative positioning is something aimed at and achieved by individual researchers, their local team, and the immediate communities of practitioners they seek to convince. Of course narrative positioning will be connected to framing, and influenced by it, and likewise framing will be influenced by narrative positioning. How this might happen is highly variable, making an interesting and important interdisciplinary challenge for historians, philosophers and sociologists of science.[8]

The case study is unpacked over three sections dedicated in turn to starting points, experiment, and interpretation. I first explain narrative positioning and then the roles it plays in experimental design and assessing evidence. Aside from reading

[7] Borah, Porismita. 2011. Conceptual issues in framing theory: A systematic examination of a decade's literature. *Journal of Communication* 61:246-263. Jasanoff, Sheila, ed. 2004. *States of Knowledge: The co-production of science and social order*. London and New York: Routledge.

[8] For pursuing this ongoing challenge further, two interesting recent starting points are Ankeny, Rachel A. and Sabina Leonelli. 2016. Repertoires: A post-Kuhnian perspective on scientific change and collaborative research. *Studies in History and Philosophy of Science* 60:18-28, and the *Isis* special issue reappraising Schaffer and Shapin's *Leviathan*. Cohen, H. Floris. 2017. A second look: *Leviathon and the Air-Pump*: Editor's Introduction. *Isis* 108:107.

literature in STEM journals, my methods included short bouts of laboratory observation (exceedingly short, merely an hour or so at a time on odd days over a two year period), and many hours of interview with the two principal postdoctoral researchers. The wording of any quotation from interviews, team meetings, or lab visits was a verbatim note taken at the time of discussion.

2. Starting points and tellability

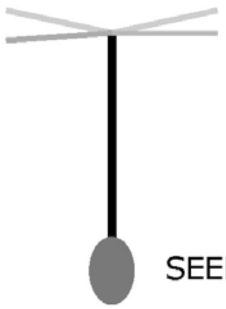
Research questions may come and go, but all have a structure, and some structures are more compelling, useful, and revealing than others. In this section I demonstrate that we can understand the making of a good question in the same way as literary theorists argue you can make a good or 'tellable' narrative. While any given research question may well be disposable depending on how research actually unfolds, even provisionally held questions play an active role in the daily management and conduct of research. My materials come from a research project in which engineers and applied mathematicians with expertise in fluid dynamics, and biologists with expertise in plant form and function, collaborated to investigate the flight of dandelion seeds. The project's framing question was 'how do dandelion seeds fly?' By contrast, the questions produced by narrative positioning were more numerous and fine grained, and as we shall see, were also essential for making room for new knowledge. After all, the question 'how do dandelion seeds fly?' can always be answered with 'the wind blows them', and any further elaboration of the process, i.e. any claim to new knowledge of the process, would land on infertile ground. The difference here pointed to can be better understood through discussion of tellability, which I return to at the end of the section.

What I am about to explain came from a constructed rationale completed by one of the central postdoctoral researchers in the first couple of months of the project. This was completed before any experiment had been organised or begun. It was they who, in collaboration with the Principal Investigators, pulled together a wide range of examples of previously completed work, many from otherwise unrelated disciplinary perspectives, in order to motivate and better define the questions for this new project. Sometimes this involved seeing analogies between earlier work and the new case, but more often it came directly from finding what research had already been done on the dandelion seed, laying all these unconnected findings out, and deciding from the overall picture what it suggested they ask next. My contribution is to interpret this activity as one of narrative positioning, the making of an epistemic viewpoint that was new in certain respects and from which askable questions can be generated, just as a tellable narrative hooks an audience and begins to stimulate anticipations of what might be coming down the road.

The following 7 starting points were compiled by one of the two central postdoctoral researchers and collated into an internal project report, which I was then given a copy of. First, some earlier biologists had focussed on a different though similar kind of plant seed, those of *Tragopogon dubius*, finding that the moment of 'abscission', when the body of the seed leaves the head of the plant, occurred more often in the presence of a strong updraft rather than during high winds approaching from the side.[9] This, the authors argued, was evidence of an evolutionary strategy aimed at maximising the length of dispersal range. Second, and beginning with a paper from 1919, a number of different mathematicians had made simplifying assumptions about the shape of each individual filament on the dandelion pappus (pappus being the name for the parachute of filaments at the top of each seed, see Figure 1 for reference), in particular assuming they conformed closely to a cylinder, extrapolating from there what the drag force must be for the whole pappus, using drag to explain the speed of descent.[10] Third, ecologists had completed work with computer simulations, also modelling with simplified

Figure 1: Simple schematic of the dandelion seed. A real dandelion pappus contains hundreds of filaments.

[9] Greene, David F. and Mauricio Quesada. 2011. The differential effect of updrafts, downdrafts and horizontal winds on the seed abscission of *Tragopogon dubius*. *Functional Ecology* 25 (3):468-472.
[10] Greene, D., and Edward A. Johnson. 1990. The aerodynamics of plumed seeds. *Functional Ecology* 4:117-125. Small, James. 1919. The origin and development of the Compositae. *New Phytologist* 18(5-6):129-156.



assumptions about the drag laws operating on the individual seed, varying the wind angles in their simulations, and likewise finding that updrafts mattered most for distance.[11] Fourth, plant morphologists interested in biomechanics had investigated the structure and material composition of the individual seed, and its behaviour in the air.[12]Aspects of this approach would be replicated for the new dandelion project, including gathering their own data from a scanning electron microscope, and pursuing photography of the seed 'in flight'. Fifth, applied mathematicians using computational fluid dynamics had focussed on the whole pappus (this time of *Tragopogon pratensis*) as the thing to be simulated, rather than focussing on individual filaments and multiplying up their effects.[13] In their terms this meant the pappus could be treated as a more or less porous disk, of which computer simulations could then predict the aerodynamic behaviour. They had concluded that the parachute of filaments maximises the drag force and helps maintain stability by being both solid *and* permeable, where others had only thought solidity significant. Some of their iterations of the simulation showed the presence of vortices, which they included as video submissions available for download with their publication.

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[11] Tackenberg, O., P. Poschlod, and S. Kahmen. 2003. Dandelion Seed Dispersal: The Horizontal Wind Speed Does Not Matter for Long-Distance Dispersal-it is Updraft! *Plant Biology* 5(5):451-454.

[12] Sudo, Seiichi, Nao Matsui, Koji Tsuyuki, and Tetsuya Yano. 2008. Morphological design of dandelion. *Proceedings of the XIth International Congress and Exposition*. Society for Experimental Mechanics.

[13] Casseau, Vincent, Guido De Croon, Dario Izzo, and Camilla Pandolfi. 2015. Morphologic and Aerodynamic Considerations Regarding the Plumed Seeds of *Tragopogon pratensis* and Their Implications for Seed Dispersal. *PloS one* 10(5):e0125040.

These first 5 starting points all concerned work either on dandelion seeds themselves, or species with flight methods that were very closely aligned to the dandelion's. By contrast the final two starting points came from outside the dandelion and its method of flight, but were nevertheless drawn in as part of positioning activity. Sixth, fluid engineering completed by materials scientists had studied the behaviour of flexible fibres in various different rates of flow.[14] Thinking of the individual filaments as flexible fibres meant the results of these simulations could be taken to speak to and describe their flow behaviours. The seventh and last was probably one of the most important influences on the design of the dandelion project, work that had been done on a different seed, that of the maple, completed by David Lentink's lab in the mid-2000s, in which he had shown that maple seeds shed vortices as they span.[15] Lentink had used flow visualisation to great effect, a method that we will come to in section 3.

To reiterate, these seven starting points do not cover all of what these researchers knew before they started. These starting points also demonstrate some things *we* already knew, for instance the project's selectivity towards the fluid dynamic questions around the seed, which we knew would be the case because the engineers and applied mathematicians on the project were experts in fluid dynamics, and because the project's interdisciplinary agenda, seen here by inclusion of aspects of the biological significance of dispersal. But this collecting together also achieved something analytically non-obvious: it built a larger picture from which sharper questions could be formulated. Likewise, it provided a range of different potential experimental research paths forward, looking for good examples to follow, or gaps in earlier approaches that could be improved on. The core of the new perspective that emerged was "To date, there have been no studies done to examine the flow structure around the dandelion in the presence of...updrafts."[16] Grinding away at literatures and building a new platform for one's

[14] Cox, R. G. 1970. The motion of long slender bodies in a viscous fluid Part 1. General theory. *Journal of Fluid mechanics* 44(04):791-810. Zhu, Luoding. 2007. Viscous flow past a flexible fibre tethered at its centre point: vortex shedding. *Journal of Fluid Mechanics* 587:217-234.
[15] Lentink, David, W.B. Dickson, J.L Van Leeuwen, and M.H. Dickinson. 2009. Leading-edge vortices elevate lift of autorotating plant seeds. *Science* 324 (5933):1438-1440.
[16] Literature review: *Taraxacum officinale*. Weekly project meeting 16/2/2016.

own project out of them is not just part of the ephemeral stuff of research life, but is a concrete epistemic activity that positions the experimenter (and their nearby community audience) in a particular relation to nature's potential, and its potential for investigation. We can better recognise the epistemic concreteness of this work by rendering it in the terms of narrative tellability.

While scholars in literary studies and narratology have developed a number of different accounts of tellability, I will rely exclusively on that of Marie-Laure Ryan.[17] Tellability is central to making one narrative dynamic, intriguing, exciting, and capable of building tension, surprise, and so on, while another narrative would fail to hold our interest for long, or we might not see the point in its being told at all. The difference, according to Ryan, "is that tellability is at least partly a matter of conceptual and logical complexity, and that the complexity of a situation, or a sequence of events, depends on an underlying system", her underlying system being 'embedded narratives'.[18] Reducing a narrative to a series of events or anticipated events, interrupted by new physical states and/or mental acts, Ryan argues that we can therefore understand interesting and tellable narratives as those that have multiple interlinking and proliferating plot lines. "It also accounts for the meaning of the expression "the plot thickens" by representing "thick" plots as a densely connected graph with an extensive parallelism of competing plans, while "thin" plots appear as linear strings dominated by the weakly integrated nodes of accidental happenings."[19] Most of Ryan's scheme is invested in how people manifest and bring about real (if imagined) worlds, and so it translates very readily to settings beyond the literary.

In the dandelion case, an experimental posture gets embedded thanks to the bringing together, and putting into relation, a set of plots, plots which provoke more or less askable questions. The question and answers to 'How do flow structures work in the presence of updrafts?' are thick, and those for 'Why do dandelion seeds fly?' are thin, because the former requires us to know a range of

[17] Ryan, Marie-Laure. 1986. Embedded narratives and tellability. *Style* 20:319-340.
[18] Ryan, pp.319-320.
[19] Ryan, p.322.

quite specific methods and analytical techniques beyond the average person's expertise, where the latter stays in the vernacular and picks out no particular epistemology. As Ryan explains, in a tellable narrative one needs to build plenty of room for inferential reasoning.[20] In the present case we have to be allowed to infer that 'flow structures' might matter, that looking at seeds 'in the presence of updrafts' might matter: there is little to infer from the question of why dandelion seeds fly, unless the reader has never seen a dandelion seed fly.

To translate and summarise, the dandelion project began by taking what were otherwise a whole host of disparate and only partially connected starting points, each of which we can now understand as prompting plots, which are the ingredients of an embedded narrative positioning: the plot of abscission in updrafts, the plot of drag laws, the plot of weather simulations, the plot of plant structure, the plot of the porous disk, the plot of the flexible fibre, and the plot of the vortex shedding maple seed. Pooled together these produced an overall embedded narrative position with all plots in play and in tension. So arranged it became possible to point out potential holes, such as where there was a fluid dynamics gap, and where existing assumptions might be challenged, such as the pre-existing emphasis on drag. This overall set of starting points and the inferences they allow for us to make produces the embedded narrative position. The essential elements of this particular new narrative position became that: 1) no empirical effort had yet been made to measure the flow around the seed during the experience of an updraft; and 2) earlier investigators had assumed that drag provided a sufficient explanation for flight. Arriving at this new embedded narrative position involved both reading past works and placing them into an intelligible historical tension with one another (not a temporal sequence in this case, as Ryan otherwise expects, but through something more like a collage), and also projections regarding action in the future: i.e. an intention to look at or do things not yet looked at or done.[21] In the following section I address how the narrative position translated into an experimental design.

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[20] Ryan, p.322.
[21] There are similarities here with Mieke Boon's 'interpretive frameworks'. Boon, Mieke. 2009. Understanding in the Engineering Sciences. In *Scientific Understanding: Philosophical*

3. Experimental design and focalisation

In this section I demonstrate how narrative positioning comes to be embodied in the design of experiments. I focus on an experiment that owed a lot to the earlier work completed by the Lentink lab on the maple seed, which had been a particularly widely celebrated case in biological engineering. Learning from this research, and building on the design of the maple seed experiment, adapting it to make it more suitable for the dandelion case, was a core feature of the dandelion project, one which produced some of its most compelling results. In this section we see how narrative positioning therefore resides in the thoughts and experimental practices of researchers. Where tellability had helped us understand the making of questions, I here draw on a second concept from literary theory, that of 'focalisation' (to be explored later). Incorporating focalisation into our accounts of experimentation provides new ways to read experiments, experimenters, their purposes, and goals. Decisions regarding what an experiment does or does not need to anticipate, or accommodate, what really matters and what we can be more ambivalent about, are decisions intent on picking out a particular point of view, one which makes it possible for new knowledge to appear.

Flow visualisation is a technique used widely by scientists and engineers intent on understanding flow (of air, fluid, etc.) around an object, and any flow behaviours caused by the material properties of that object. The aim is to gain visual evidence of the airflow in order to study its patterns and stabilities. The way this is done, is to fix your object of interest within the field of view of a camera. You then start forcing a controlled stream of air around it, in the dandelion case this was from beneath an individual seed, because as we saw earlier, they had already decided updrafts were more fundamental than horizontal winds. Once you have all that in place, you then fill the air around the object with fine particles of smoke, using a standard smoke machine, making sure the air around the object is well saturated.

Perspectives, eds. De Regt, Henk W., Sabina Leonelli and Kai Eigner. Pittsburgh: University of Pittsburgh Press, p.261.

You then fire a laser at particular areas of space around the object that you want to illuminate, taking in a range of different planes, in order to build up a more complete picture of the flow around the object and to find the most revealing angles. The camera will then take photographs of the smoke particles illuminated by the laser, and you can look for patterns in the smoke in the photos. A photograph of an early iteration of this experimental setup made for the purposes of prototyping is available as Figure 2, while a photograph of the final experimental setup used is available in the *Nature* paper reporting their results.[22] Interventions here include affixing the seed to a solid support so that it will not fly away and out of your camera focus at higher rates of flow, and filling the air with very fine smoke, avoiding larger particles that are likely to produce their own behaviours.

In the weeks leading to the initial design of this experiment one of the lead postdocs spoke of "trying to imagine what it is like to be one of the pappus".[23] During a team meeting, one of the PIs recommended that the experiment did not need to worry about the tips of each of the individual filaments interacting with each other because they are, in terms of the aerodynamics, too far apart "the physics don't see each other".[24] In an early preliminary experiment, a lead postdoc tried balancing one seed on top of another, using the prototype updraft apparatus to pass a flow of air around them, and noticed that the top one wobbled a lot more than a single seed left on its own. This, they explained to me, meant "Either [the top one is] amplifying the physical movement of [the] bottom seed or there is a

Figure 2: Very early iteration of the apparatus needed for the flow visualisation experiments. This was a prototype setup used to test generally important features, such as ability to control airflow rate, ease of focussing on the seed with camera equipment, and the different kinds of gauze or other flow stabilising materials that might be needed.

[22] Cathal Cummins, Madeleine Seale, Daniele Certini, Enrico Mastropaolo, Ignazio Maria Viola, and Naomi Nakayama. 2018. A separated vortex ring underlies the flight of the dandelion. *Nature* 562:414-418.
[23] Note taken during laboratory visit 4/12/2016.
[24] Note taken during team meeting 1/3/2016.

wake being created by the one at the bottom".[25] They further imagined life at seed level in other ways, in drawing on the data produced by the scanning electron microscope, and by "flying over the dandelion"[26] as another postdoc referred to it when explaining the computer visualisations resulting from sending seeds to be analysed by computed tomography. The latter also added further encouragement to a change in their mathematics, turning each filament into a truncated cone rather than leaving them as cylinders. In time, with more collaboration and more reading, the idea to treat the whole parachute of the pappus as a porous disk also began to emerge so that, as one of the lead postdocs explained "We want to distinguish between whether it is behaving like independent filaments or like a disk".[27] The plot referred to earlier as 'starting point' 5 therefore actually emerged some months into the project, though still before the flow visualisation experiments were attempted. And in another team meeting, after the group watched a video of a seed parachute folding up on contact with water, one of the PIs became particularly excited by this possibility: "for us what we want is a similar video for all the aerodynamic properties working on the [individual] seed.

[25] Note taken during laboratory visit 8/6/2016.
[26] Note taken during team meeting 5/4/2016.
[27] Note taken during laboratory visit 4/10/2016.

A second video showing how different conditions change the trajectories. This is how you motivate doing the mathematics model." Imagining a range of future videos was a way of thinking about the seed aerodynamics and their future audiences all at once, a significance that I return to in Section 4.

All of these experiences add further evidence of narrative positioning because they pick out some of the fine-grained questions derived earlier, but here putting them into experimental action. They focus our attention on the airflow around the seed, and also often invite us to take a seeds' eye view. Appreciating experimental design as embodying a narrative position, we easily recognise how experiments and narratives are always subject to revisions, limiting without too greatly prejudicing the range of possible answers which might follow the anticipated work, including the possible answer that *there is nothing interesting whatsoever about the flow around the dandelion seed*, and that its aerodynamics really can just be explained by drag. The postdoc leading design of the flow visualisation experiments was well aware that they might find nothing outside of drag, at which point the project might have to slightly change focus, i.e. rearrange the plots to produce a different narrative position. If that occurred the postdoc thought it most likely they would have to switch to explaining only the stability of the seed's fall, or in my terms, increase the value of a stability plot over a flight plot.[28] The hope however was to avoid this outcome and instead find interesting vortex behaviour in the flow. What that vortex behaviour might be could not be guessed ahead of time, nor its potential causes, which could have been to do with the properties of each filament, the body of the seed, the stem, the arrangement of all these parts in relation to one another, and so on. Focalisation provides terms in which to understand the epistemic work of narrative positioning and repositioning.

As with tellability, focalisation has been defined and interpreted in a number of different ways by scholars in literary studies. For simplicity, I will rely solely on that of Gérard Genette in the 1980 English translation of his *Narrative Discourse*

[28] Note taken during laboratory visit 4/12/2016.

(1972).[29] Understanding focalisation is a way for the philosopher to carve up the experimental setting and representations of its results in new ways. The cutting points concern who or what is taken to be our narrator: at times the local experimenter or the united voice of a disembodied team; at other times the apparatus; and at still other times the phenomena under study. As part of his overall theory of narrative discourse, Genette highlights the ways in which different passages of a text will 'focalise' differently. Some will be written in such a way that the only perspective we are receiving, the perspective that is on transmit, is that of an omniscient narrator. Other times there is more of a balance between the voice of the narrator and the other voices available in the text, so that no single character or the narrator is thought to be concealing more, or to know more, than any other. Last there are times where our narrator seems to say less, or perhaps know less, than the other voices at hand, offering partial pictures in contrast to a larger whole that we only glimpse or get given a limited explanation of. All three ways of managing focalisation, which Genette calls non-focalisation, internal focalisation, and external focalisation, are present in the dandelion case as it has been presented so far.

Non-focalisation has occurred whenever a project participant has spoken, or designed their experiment, in ways that preclude other possibilities. It was, for instance, never going to be the case that they became concerned with interaction effects between the tips of the filaments because 'the physics' had already spoken through a PI. Internal focalisation was the most common in this team work, allowing different disciplinary perspectives to come forward and all be present in the phenomena, including voices of apparatus (represented in graphs and alike), and the perspective of the seed, as when one wobbled atop the other. Here an experimental design can be appreciated as more or less giving phenomena a chance to shine. The third, external focalisation, is more difficult to evidence but still present. Rarely was it the case that our principal narrators let it be known that something outside themselves could be calling the shots, even during the very early tentative phases of the project. The decision to improve on the mathematical

[29] Genette, Génette. 1980. *Narrative Discourse*. Oxford: Basil Blackwell.

abstraction, swapping from cylinders to truncated cones, might be one example, as the decision was inspired by recognition that nature is composed of something more specific, but which was going to be left beyond analysis. The best evidence is no doubt the general anxiety that the experiment might prove that drag is the only explanation of seed flight. The very real possibility of that future, one which was out of their control, meant that enthusiasm for alternative plots, such as the stability question, had to keep being stoked, just in case they were called upon. But if it weren't for my study of this work in progress no evidence of that anxiety, and therefore much less evidence of external focalisation, would be available to us.

Keeping an eye on distinctions of focalisation is a way to bring further clarity to issues such as the theory-ladenness of observation, the role of non-human actors in knowledge production, and the need (or otherwise) for a general theory of evidence. Knowing that observation is theory-laden, philosophers of science and engineering have primarily set about analysing observational practices, leaving the notion of what it means to be an observer under-theorised. Now that philosophy of science is edging ever-closer to a phenomenology of experimentation, as can be glimpsed in a recent edited collection on *Scientific Understanding*, how different elements of an experimental design focalise different kinds of narrator and characters is one path forward.[30] The claim that apparatus and seeds have something like voices may well resonate with work in the sociology of science, Latour and Callon are the first to spring to mind, and the notion of nature speaking is reminiscent of Flecks' signals of resistance, but these would have to be investigated in more depth before I could be taken to be arguing for a similar or derivative position.[31] Bill Wimsatt has already made the case that narrative knowledge is an essential part of science and engineering precisely because it is excellent for dealing with, and drawing in, a range of different kinds of evidence

[30] De Regt, Henk W., Sabina Leonelli and Kai Eigner eds. *Scientific Understanding: Philosophical Perspectives*, eds. Pittsburgh: University of Pittsburgh Press.
[31] Latour, Bruno. 1987. *Science in Action*. Cambridge, MA: Harvard University Press. Callon, Michel. 1984. Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay. In *Volume 32 Special Issue: Sociological Review Monograph Series: Power Action and Belief A New Sociology of Knowledge*, ed. John Law. Fleck, Ludwik. 1979. *Genesis and Development of a Scientific Fact*. My thanks to a reading group that took place at the University of Leeds some years ago for my close reading of Fleck.

and different perspectives regarding that evidence.[32] Focalisation therefore offers tools for taking an appreciation of theory and practice 'as montage' further and deeper into experimental practice. Through narrative positioning we see better how experiments create a stage on which new knowledge can appear. In making this argument it no doubt helps that we are dealing with a case study involving something very much like the arrangement of a theatre stage, complete with laser light show, photography, and a smoke machine (of a model that had won a Technical Oscar no less). Nevertheless the relational aspects of the experimental setup between phenomena, world, operator of apparatus, and the apparatus itself, matter much more generally and in less theatrical settings.

4. Interpretation and synoptic judgement

Having demonstrated the importance of narrative positioning for question making and the design of experiments, this section takes us to a third and final step: that of gaining assent to new knowledge. The making of an interesting, well-informed, and plausible question would be for nothing if it could not be manifested in an experimental design, and likewise an experimental design means nothing if it is insufficiently persuasive, reliable, and interesting to prompt agreement that new knowledge has indeed been produced. Narrative positioning is once again key to understanding how new knowledge claims are set up and made, which I demonstrate through particular attention to the evidence produced by the flow visualisation experiments and the kinds of judgement or interpretation that it invites. Where I have previously used concepts developed in literary theory (tellability and focalisation), I here make use of the philosophy of history and Louis Mink's notion of 'synoptic judgement', which has been drawn upon recently by a range of philosophers of science dedicated to improving and expanding our understanding of narrative in science.[33] When assessing research completed by

[32] Wimsatt, William C. 2007. *Re-Engineering Philosophy for Limited Beings: Piecewise Approximations to Reality*. Cambridge, MA: Harvard University Press, pp. 154-157.

[33] Beatty, John. 2017. Narrative possibility and narrative explanation. *Studies in History and Philosophy of Science* 62:31-41. Hurwitz, Brian. 2017. Narrative constructs in modern clinical case reporting. *Studies in History and Philosophy of Science* 62:65-73. Morgan, Mary S. 2017. Narrative ordering and explanation. *Studies in History and Philosophy of Science* 62:86-97. Norton Wise, M.

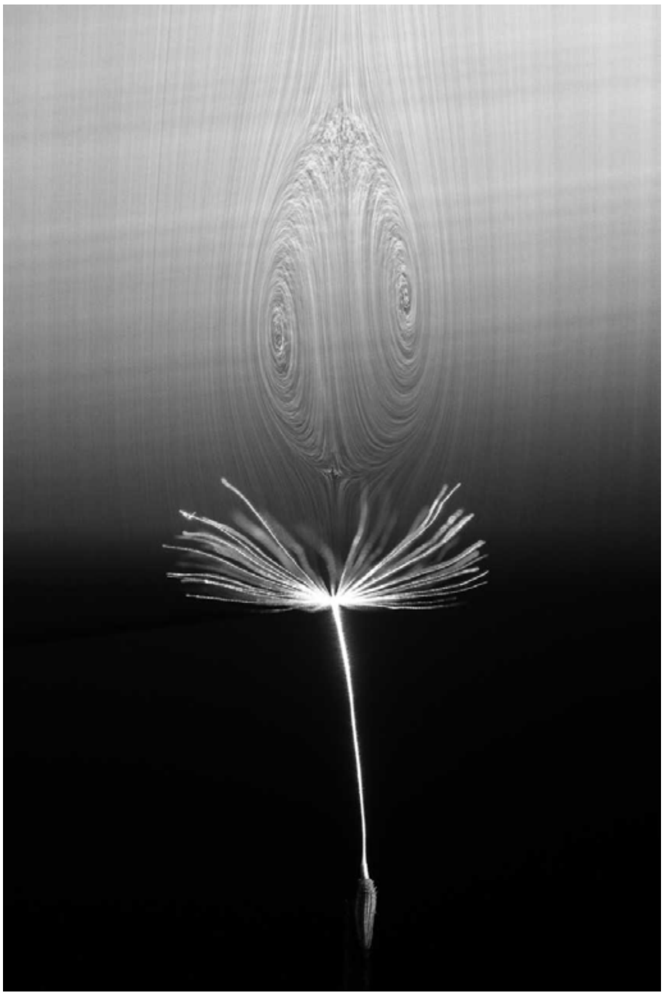
others, the audience is invited to step into the shoes of the original researchers, look around, and decide for themselves if they agree with the conclusions drawn, disagree with certain elements, and so on. To some extent this will be a vantage point built by having shared similar experiences to those recorded by the dandelion researchers.[34] Narrative is key to explaining why some kinds of evidence are better at provoking dissemination and inspiring assent to new knowledge than others. This is because narrative positioning increases opportunities for synoptic judgement, and synoptic judgement is a very effective way to gain assent to new knowledge.

The photographs and videos produced by the flow visualisation experiment have been central to the successes of the dandelion project. An example is included here as Figure 3, further examples can be found in their *Nature* paper, and another won an annual photography competition organised by the UK Fluids Network, a national special interest group of researchers in fluid dynamics. The photographic results showed that there was indeed an interesting vortex phenomena being created by the seed, which for a brief period of time was referred to as a 'halo vortex'. This name was lost prior to publication, in exchange for something that conveyed more information about the phenomena, though as you can see, halo vortex pays tribute to what we find in the images and why they are interesting. "We found a stable air bubble (a vortex ring) that is detached from the body, yet steadily remains a fixed distance downstream of the pappus...Bluff bodies (such as circular disks) may generate vortex rings in their wake, but these are either attached to the body or shed from it and advected downstream. The vortex ring in

Figure 3: Illustrative example of one of the many flow visualisation photographs taken showing the presence of an 'SVR'. Photograph kindly provided by, and credit to, Cathal Cummins, Madeleine Seale, Enrico Mastropaolo, Ignazio Maria Viola, and Naomi Nakayama.

2017. On the narrative form of simulations. *Studies in History and Philosophy of Science* 62:74-85. Roth, Paul, A. 2017. Essentially narrative explanations. *Studies in History and Philosophy of Science* 62:42-50.

[34] Leonelli, Sabina. 2009. Understanding in biology: The impure nature of biological knowledge. In *Scientific Understanding: Philosophical Perspectives*, eds. De Regt, Henk W., Sabina Leonelli and Kai Eigner. Pittsburgh: University of Pittsburgh Press, p. 199.



the wake of the pappus is neither attached nor advected downstream, and we therefore called this vortex a separated vortex ring (SVR)."[35] Though we might disagree on final interpretation, there is little arguing with the evidence of a vortex being produced, remaining stable, and its being detached as recorded in these videos and photographs. But there would be little understanding them, or recognising how they demonstrate new knowledge, were it not for all the narrative positioning work that went on before, and which this kind of evidence also contributes to. The narrative position is paid off by the images at the same time as the images further perpetuate the narrative position. This process continues in publication. For instance, it is explained that though the best and clearest photographs of the vortex were taken at higher rates of flow, when the seeds had to be fixed to a support to prevent them flying off, they used the same ten seeds

[35] Cummins et al. 2018, p. 414.

for both free flying and fixed flow visualisation.[36] The reader is asked to step inside the experimental process from start to finish, see how correspondences were made, where trust can reside, and so on. More obviously, they are asked to peruse the videos and photographs.

These visualisations are persuasive thanks to narrative in precisely the same way that Norton Wise has argued for visualisations in chemistry.[37] For Norton Wise, different methods for visualising research and research outputs are essential for making complex phenomena legible. As he writes "visualization is the only effective means for following a [complex] process". We have already seen that the engineers and scientists in my case also placed a great deal of emphasis on being able to see, by various different means, what was or might be happening, emphasising the need to make movies of the phenomena where possible. Norton Wise goes on to argue that the ways in which visualisations convince us of new knowledge is largely thanks to their narrative features, bringing in the work of philosopher Louis Mink on the making of historical narratives, and what Mink terms synoptic judgement. Mink was interested in explaining what is happening when a historian draws together a range of different influences and causes (plots) to produce a historical narrative, to make coherence out of that complexity. As Mink wrote in 1966 "the distinctive characteristic of historical understanding consists in 'seeing things together' in a total and synoptic judgement which cannot be replaced by any analytic technique".[38] Norton Wise goes beyond Mink by demonstrating the presence of this analytic technique in the sciences. Complex phenomena are made manageable thanks to some abstracting assumptions and the making of videos that we can watch and interpret for ourselves, based on past experiences and understandings. The same occurs with the dandelion case.

On seeing photographs such as Figure 3, and the set of photographs that it comes from, we are getting a visual guide into something that is otherwise

[36] Cummins et al. 2018, p. 419.
[37] Norton Wise, 2017.
[38] Mink, Louis (1987). *Historical understanding*. Edited by Brian Fay, I. O. Golob, & R. T. Vann. Ithaca and London: Cornell University Press, as quoted in Norton Wise, 2017.

overwhelmingly complex. It is not as though this picture is detailing how or why the smoke particles make this arrangement, or trying to provide the mathematical or structural insights into their production. Much of the article publishing these results is indeed arguing for particular answers to these questions, but those potential answers are given credence and made worthy of our attention by the stark flow visualisation results. The community of researchers see the point that the flow visualisation results are making because the photograph delivers it to us all at once. Synoptic judgement concerning the presence of the SVR is made possible by slowing the phenomena down, to a snapshot, and by magnifying it to a scale we can more easily see.

The videos create an opportunity for synoptic judgement all of their own. The first shows a freely floating seed passing through the plane of illumination, out of focus, then in focus, then out again, allowing us to see a vortex in cross section. In comparison with the photographs it is less easy to see the shape of the flow, and we lose the stability of the photograph, but in return we gain dynamism. We see how much the presence of the swirling vortex is directly dependent on the presence or absence of the seed, rather than some feature of the apparatus, and that the vortex does not seem to disturb the seed. Everything looks *right*. This video also primes us for the latter ones, in which the seed is fixed to a solid support so that higher and higher rates of flow can be used without it disappearing off into the air. They provide a translational sequence of events demonstrating how alike the vortex is both when the seed is free *and* when it is fixed, further developing our general sense of the phenomena and how it works, and the extent to which the experimenters are providing a reliable account of the phenomena. When it comes to their argument that the explanation for the phenomena is due to the overall head of the pappus acting as a more or less porous disk, they include further video evidence, but this time of silicon disks of their own fabrication, designed to emulate the pappus structure. Photographs and videos demonstrating the same kind of vortex being produced by these silicon disks then add to the overall translational sequence: first show the new phenomena; then decompose it into the parts that are believed to matter most; then once again demonstrate the presence of detached vortices that do not shed but which are now due to the silicon disks. The argument of their paper, and their results, can be grasped at once thanks to these visualisations, which facilitate narrative positioning by synoptic judgement.

5. Conclusion

This paper has drawn upon analyses from literary studies and the philosophy of history in order to explore new terrain in the philosophy of engineering concerning understanding, experimentation, and interpretation of evidence. Concepts such as tellability, focalisation, and synoptic judgement have been applied to cases in engineering, and brought together under the larger function of 'narrative positioning'. I have by no means exhausted the number of ways in which narrative positioning is achieved in engineering and the sciences, so the concept may therefore act as an encouraging bridge between the otherwise very distant fields of literary studies and the philosophy of science and engineering.