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ABSTRACT

One of the more difficult elements to teach well in the introductory technical writing classroom is rhetorical form. Although textbooks have gotten much better than in the past at teaching this element, some still imply that structure is a matter of filling up a set form with content. One way to help students avoid this difficulty is to introduce them to historical examples of technical communication to demonstrate three principles about form: (1) form is conventional and has changed over the centuries; (2) earlier technical communicators connected form and thought in sophisticated ways; and (3) early writers used various formal strategies to communicate to a particular audience to achieve rhetorical goals. A good example of 18th-century scientific discourse to use in the contemporary classroom is a section from James Bradley's 1748 "A Letter to the Right Honourable George Early of Macclesfield concerning an apparent Motion observed in some of the fixed Stars," which provided the first evidence of nutation, or the wobbling of the earth on its axis due to the gravitational influences of the sun and the moon. Presented before the Royal Society, the paper contains a classic example of analytic arrangement, a method of organizing a discourse so that it at least appears to recreate the steps in the scientist's experimental problem-solving process. Because of the rhetorical power of analysis, contemporary students would benefit from studying its application in 18th century scientific discourse. (RS)

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Bradley's Nutation, 18th-century Analytic Arrangement, and the Contemporary Technical Communication Classroom

One of the more difficult elements to teach well in the introductory technical writing classroom is rhetorical form. Although textbooks have gotten much better than in the past at teaching this element, some still imply that structure, whether it be based on the modes of discourse or on various report or letter formats, is a matter of filling up a set form with content. Such an approach has a number of weaknesses. One is that students leave the course with the misconception that the highly conventional forms that they learned are universally used in all segments of business and industry. A second, more damaging result is that student writers become convinced that thought and form are disconnected, that good writing consists of filling in the blanks. One way to help students avoid these traps is to introduce them to historical examples of technical communication to demonstrate three principles about form: first, that form is conventional and has changed over the centuries; second, that in may cases, earlier technical communicators connected form and thought in sophisticated ways; and, third, that early writers used various formal strategies to communicate to a particular audience to achieve rhetorical goals. One good example of 18th-century scientific discourse to use in the contemporary classroom is a section from James Bradley's 1748 "A Letter to the Right honourable George Early of Macclesfield concerning an apparent Motion observed in some of the fixed Stars," which provided the first evidence of nutation, or the wobbling of the earth on its axis due to the gravitational influences of the sun and the moon. Presented before the Royal Society on February 14, 1747, the paper contains a classic example of analytic arrangement, a method of organizing a discourse so that it at least appears to recreate the steps in the scientist's experimental problem-solving process. This method not only has the advantage of clarity; it also convinces skeptical readers to accept unexpected or disturbing results.

Background

Although Bradley was one of 18th-century England's greatest observational astronomers, he received no formal training in astronomy. He attended Balliol College, Oxford, when the university was best known for its classical curriculum, and took his B.A. in 1714 and his M.A. three years later. He was informally trained in astronomy by his uncle, James Pound, a skilled amateur astronomer, who introduced his nephew to Edmond Halley, perhaps the most famous astronomer then working in England who identified the famous comet. Based on his early promise and interest, Bradley was elected to the Royal Society in November 1718, but, in order to support himself, he took clerical orders the following year and accepted a vicarage in Bridstow. In 1721, however, he resigned his ecclesiastical position upon his appointment as the third Savilian professor of astronomy at Oxford and initiated a series of celestial observations that led to significant astronomical discoveries. Bradley is primarily remembered for his work on the aberration of light, which he reported to the Royal Society in 1729. While replicating the failed 1669 observations of the star Gamma Draconis by Robert Hooke, Bradley found that the star shifted a full 1 minute in arc in an unexpected direction; after years of work, he concluded that the shift was due to the aberration or bending of light which resulted from the finite speed of light and the earth's forward motion in its orbit. His calculations offered the first mathematical proof of the speed of light (183,000 miles per second) and lent experimental support to both the Copernican hypothesis and Newton's theory of gravity.

While conducting this series of observations, Bradley noticed a second apparent movement of the fixed stars, a movement that could not be explained by aberration alone. Through a second set of observations lasting over twenty years, he determined that this movement was due to the precession of the equinoxes and to a slight nutation or nodding of the earth on its axis due to the gravitational effects of the moon and the sun. These findings are the subject of my paper, which examines Bradley's analytic presentation of his results to the Royal Society.

Analytic Arrangement

As Wilbur Samuel Howell asserts in *Eighteenth-Century British Logic and Rhetoric*, "the changes that took place in logical and rhetorical doctrine between 1700 and 1800 are perhaps best interpreted as responses to the emergence of the new science" (5). One of the most significant of these changes was an attempt to explain the rhetorical and logical nature of expository, informative, or scientific prose, a category of communication largely neglected by classical theory and practice. One of the most important concepts that 18th-century logic and rhetoric developed to explain informative discourse was analytic arrangement, a strategy used by many experimental scientists of the period to communicate the results of their investigations. This method, whose roots grow from ancient mathematics, developed two related strands within 18th-century logical and rhetorical theory. One strand connected analysis to the cognitive process of discovering new information using the experimental method and is closely tied to the scientific goal of identifying effects and their causes. The second, more traditionally rhetorical strand, was concerned with moving an audience to accept an initially unfamiliar, surprising, or even repugnant conclusion to a chain of reasoning. While almost every major logician and rhetorician of the period at least mentions analysis, the most important English discussions appear in William Duncan's *The Elements of Logic* (1748), George Campbell's *The Philosophy of Rhetoric* (1776), Hugh Blair's *Lectures on Rhetoric and Belles Lettres* (1783), and, especially, Joseph Priestley's *A Course of Lectures on Rhetoric and Belles Lettres* (1788). This last book offers the most thorough discussion of the concept in 18th century rhetoric. Given the publication dates of these works, I am not arguing that the rhetorical theory influenced Bradley's 1748 exposition on nutation; I am arguing the opposite: that the practice of using analysis by Bradley and other scientists created the need for logics and rhetorics to theorize about the method.

William Duncan, in his 1748 *Elements of Logic*, provides one of the earliest attempts in England to establish the cognitive basis of analysis. Method in general, according to Duncan, is the fourth and last power of the understanding used in logical theory and practice, following apprehension, judgment, and reasoning. After the first three mental operations, he argues, thinkers must be able to organize their thoughts into some sort of larger system in order to understand easily the relationships among their various parts. In other words, working within an Lockean associationist context, Duncan assumes that all extended thought consists of connecting known to unknown ideas, and method offers a system for organizing these associations into a connected whole. The need for such a system grows from the limitations of the human mind, which cannot grasp a complex system without organizing it so that the thinker can see the relationships among the parts. Duncan uses the analogy of a complicated multiplication problem to demonstrate the need for method in an investigation. If a person looks at two huge numbers, she cannot, via intuition alone, discover their multiplicand. But if that same person follows the rules of multiplication step by step, she can arrive at that answer with little effort because each step is within her cognitive power. By following each small step, the mathematician is able to connect the first two numbers with the answer.

Analysis, which Duncan tellingly calls the "method of invention," is particularly useful for organizing the thoughts of thinkers moving from observations of particular effects to the causal principals that explain them. In other words, the method is designed to guide thinkers from known, observable effects to unknown, hidden causes. In the case of Bradley, he noticed the small and unexplained movement in the fixed stars, and, through painstaking observation and reasoning, traced those effects back to their cause, the wobbling of the earth as it rotated on its axis. As Duncan describes the method, "When truths are so proposed and put together, as they were or might have been discovered, this is called the *Analytic Method*, or the *Method of Resolution*; in as much as it traces things backward to theirSource [sic], and resolves *Knowledge* into its first and original Principles" (275). To illustrate analysis mechanically, Duncan uses the popular Neo-Classical metaphor of the watch, which, he argues, can be examined analytically if one begins with the unassembled parts and figures out how to put them together so that the watch works as a whole mechanism.

Rhetoricians writing later in the century echo Duncan's discussion of analysis. In *The Philosophy of Rhetoric*, George Campbell identifies analysis as the ground of all reasoning based on experience. Analysis has the power to communicate new knowledge gained from experience because it guides the thinker/writer to "ascend from particulars to universals" (62). It is, therefore, closely related to induction and the experimental method of science. In his *Lectures on*

Oratory and Criticism, Priestley notes that "the *analytic* method of communicating any truth is, properly speaking, nothing more than a copy of the method if its *investigation*" (56) and then refers the reader to a logic like Duncan's for a more detailed discussion of its logical structure.

Rhetorics of the period, however, also discussed analysis as a rhetorical rather than a logical strategy. In his *Lectures on Rhetoric and Belles Lettres*, Hugh Blair discusses analysis as a purely communicative technique. When using the method, he argues, the rhetorician "conceals his intention concerning the point he is to prove, till he has gradually brought his hearers to the designed conclusion. They are led step by step, from one known truth to another, till the conclusion be stolen upon them, as the natural consequence of a chain of propositions" (119). Blair connects analysis with the dialectic method that Socrates used to lead his interlocutors to accept conclusions with which they did not initially agree. The method of analysis, therefore, is particularly useful when communicating with a hostile audience unwilling to accept an unpleasant or unexpected conclusion.

Priestley also suggests some rhetorical strategies connected with analysis. He argues, for instance, that, while analysis should at least loosely recreate the investigative process, the writer need not "relate every step of any actual process" (56) but can edit the method for observations foreign to the purpose and dead end hypotheses that tax the reader's patience or distract from the main point of the discourse. Also, when writing on topics about which many prejudices cluster, the writer of an analysis might have to introduce elements extraneous to the investigation itself designed primarily to placate a skeptical reader. Such additions might include background information and various justifications for the investigation. Finally, Priestley suggests that, when writing analytically on a topic about which few hold prejudices, the writer/investigator organize the analysis by means of the "method of approximation" (57). In this case, the writer does not trace exactly the order of his investigative process. Instead, he should first give the evidence that makes the hypothesis seem probable and then move to more telling evidence before offering last the *experimenta cruci* that proves the hypothesis without a doubt (57). Blair and Priestley both suggest, therefore, that the investigator/writer organize his discourse with a keen sense of the audience and its attitude towards the conclusion being argued. The rhetor need not present the steps in the investigative process in the exact order in which they occurred, and she can leave out steps if they don't contribute to the reader's understanding of the conclusion.

Central to both the cognitive and rhetorical power of analysis is the assumption that a discourse organized according to the process by which the investigator arrived at a conclusion possessed considerable persuasive power. The reader who experiences this process will tend to accept the conclusion if he can follow all the steps and if there are no logical breaks between each step. This reader will also be willing to grant assent to the conclusion if she identifies with the writer's cognitive struggle to discover the truth and if the process itself makes sense.

Bradley's Paper

As Priestley suggested in his rhetoric, most discourses are of a mixed kind, sometimes using analysis, sometimes other methods, including synthesis, which is a deductive movement from an accepted truth to truths logically connected to it. Bradley's paper falls under this mixed type. It has three distinct sections. The first is an introduction, which justifies observational astronomy, gives an overview of Bradley's projects, and identifies the need for more accurate astronomical instruments. The second section consists of the application of analysis, which recapitulates Bradley's thought processes as he worked through the problem until he reached the solution to it in the form of a hypothesis. The third section presents detailed mathematical support to prove his hypothesis. This paper will concentrate on the middle section, the movement from problem to hypothesis.

Bradley identifies the problem early in his letter, and expresses the bewilderment he experienced when he first confronted it. While working on the aberration of light of the fixed stars due to the finite speed of light and the earth's orbit, he discovered an inconsistency in his data which led him to identify a second cause of motion of the stars. As he puts it, "my attention was again excited by another *new Phenomenon, viz*. An annual Change of Declination in some of the fixed Stars; which appeared to be sensibly *greater* about that time, than a Precession of the Equinoctial Points of 50" a Year would have occasioned" (2). This inconsistency in the data suggested that he had identified an effect due to at least one other cause that he was "then at a Loss to guess, from what Cause that greater Change of Declination proceeded" (3). Typical of analysis, Bradley not only explains what he discovered, the inconsistent data, but he also expresses his bewilderment concerning it. He decided, therefore, that after finishing his project on the aberration of light, he would begin a second series of observations to isolate that causes of this second effect.

Early in his observations, Bradley recognized, however, that some objections might be raised to his procedure, so he made certain that his process for making the observations was sound. Consequently, he discussed in some detail the "supposition" upon which his method was based. This supposition was that his instrument was set up in the same direction throughout the observations and that the movement of the stars was not the result of slight shifts in the position of his instrument. As Bradley put it, "I suppose, that the Line of Collimation of my Telescope has invariably preserved the same Direction, with respect to the Divisions upon the Arc, during the whole Course of my Observations" (8). Bradley was so concerned about objections to his method that he discussed in detail how he thought through the problem during the early stages of his observations. First, he pointed to the astronomers of the Academy of Sciences who used a telescope similar to his to observe stars on a expedition to the Arctic. Since they managed to maintain the collimation of their instruments even though they had to move and set them up several times, it followed logically that Bradley would have maintained his line of collimation since he never had to move his telescope over the entire twenty years of observations. Second, he argued that the observations themselves supported his supposition. He decided early on "to continue [his] Series of Observations for so many years" (8) to make certain that they were accurate. At the end of his observations, he found inconvertible evidence that his instrument was accurate: "at the End of the full Period of the Deviations which I am going to mention, the Stars are found to have the same Positions by the Instrument, as they ought to have, supposing the Line of Collimation to have continued unaltered from the Time when I first began to observe" (9).

While he was satisfied that his method was sound, he still wondered about his instrument, and retraced his thought processes as he ruled out instrument inaccuracy as the cause of the apparent movement of the stars. First, he suspected that the changed in position of the stars was due to a problem with the material of his instrument. Perhaps, he hypothesized, the material underwent some sort of a change or perhaps the position of the instrument had shifted. To rule such causes out, he examined the instrument carefully. He reports that he checked the mountings of the arc on which measurements were made and found those mountings firm. He also checked the wire that "lies in the focus of the Object-Glass" and found that stable and accurate (9). The only other problem could be the plummet or plumb line used to level the instrument. He remembered that the wire the held the plumb had broken "three or four times" during the first year of observations and had to be replaced. Perhaps, he reflected, the different readings were due to the different lines that he used. To test this hypothesis, he set his instrument using one plumb line and replaced it with another and then another. He found no major changes in his readings and concluded that "no sensible Error could arise from the Use of different Plumb-lines" (10). Since both the collimation of the instrument was accurate and the parts that composed it were fine, he concluded that the movement of the stars had to be due "not to any Imperfection of my Instrument" but to natural causes that he had yet to identify. Bradley recreates his thought process at the time by writing "Having then, from such Trials, sufficient Reason to conclude, that these *second* unexpected Deviations of the Stars, were not owing to any Imperfection of my Instrument; after I had settled the Laws of the Aberrations arising from the Motion of Light, &c. I judged it proper to continue my Observations of the same Stars; hoping that, by the regular and longer Series of them, carried on tho' several succeeding Years, I might, at length, be enabled to discover the real Cause of such apparent Inconsistencies" (10).

Bradley then attempted to establish the true causes of the phenomenon that he had noticed. To make his discoveries convincing, he traced the steps of his thinking as he moved from partial to complete understanding of the causes that explained the unexpected change in the position of the stars. He notes that he "began to guess what was the real cause of" these movements fairly early in his observations but had to continue the observations for many years before he was certain of his conclusions.

The first step in his analysis was to point to a pattern that he noticed in the data. As he comments, "It appeared from my Observations, that, during this Interval of Time, some of the Stars near the Solstitial Colure, had changed their Declinations 9" or 10" less, than a Precession of 50" would have produced; and, at the same time, that, others near the Equinoctial Colure, had altered theirs about the same Quantity more, than a like Precession would have occasioned: the North Pole of the Equator seeming to have approached the Stars, which come to the Meridian with the Sun, about the Vernal Equinox and the Winter Solstice; and to have receded from those, which come to the Meridian with the Sun, about the Autumnal Equinox and the Summer Solstice" (11). In other words, Bradley noticed that the changes in the position of the stars corresponded to the changes of the relationships between the earth and the sun and the moon as the seasons changed.

He immediately "suspected," he notes, that "the Moon's Action upon the Equatorial Parts of the Earth might produce these Effects" (11). He remembered Sir Isaac Newton's work on gravity. Since Newton's principles of gravity suggested that the sun and the moon might influence the precession of the equinoxes (the circular motion of the celestial poles around the poles of the ecliptic), these two celestial bodies might in some way be causing the unexpected change in position of the stars. Since the sun maintains the same inclination to the Earth's equator while the moon changes its angle over time, Bradley reasoned, it would make sense that the moon was the main cause of the phenomenon. Perhaps, then, the apparent movement was caused by the precession of the equinoxes.

But the precession of the equinoxes did not appear to explain the full effect that his observations identified. Some of the stars that Bradley observed near the "Solstitial Colure" moved in "a manner contrary to what they ought to have done, by the Increase in the Precession"

(12). Another cause was at work. Bradley examined particularly Gamma Draconis and another small star. Their apparent movement, Bradley concluded rather boldly, "might proceed from a Nutation [a wobbling] in the Earth's Axis" (13).

But what caused this nutation? After more observations of stars in relation to the position of the moon in relation to the Earth, Bradley concluded that the real cause of nutation was the gravitational influence of the moon on the Earth's equator. Since the angle of moon in relation to the equator changed as the moon revolved around the earth, the gravitational influence varied, causing the earth the wobble so that the northern axis moved in a small circle. The final proof came when Bradley continued his observations through an entire "Period of the Moon's Nodes" and found that the stars returned to their original positions after one complete cycle.

So the true causes of the apparent movement of the stars was a combination of the precession of the equinoxes and the nutation of the earth. While the precession of the equinoxes had been known since classical times, nutation was not known until Bradley discovered it. As his observations proved, nutation has a period of about 18.6 years. Bradley's contribution, therefore, was to provide the most accurate explanation to date about how these two types of earthly movements functioned together.

Conclusion

The analytic method that Bradley used has two primary advantages over the method of presenting a hypothesis first and then following it with proofs and explanations. First, analysis is a dramatic method of presentation, one that encourages the reader to identify (in the Burkean sense) with Bradley as he first isolates the problem (that the fixed stars appeared to move in space) and then reasons through to the problem's causes. Readers who follow the chain of reasoning, who accept each link in the logical chain that Bradley forges, will tend to accept Bradley's conclusions, in part because they will have been prepared to accept them. To reject his solution, readers would have to reject some stage in his analysis. Second, the method offers an excellent strategy to encourage readers to accept unexpected conclusions. After all, Bradley presented a new phenomenon--that the earth nutates or wobbles on its axis--that would not be readily accepted by an audience unprepared for such a new and surprising claim.

Because of the rhetorical power of analysis, contemporary students would benefit from studying its application in 18th century scientific discourse. Analysis offers an excellent way to explain complicated and controversial conclusions, one that technical communicators would find useful in many rhetorical situations.

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