The Role of Mathematics in Culture

W. James Bradley
Calvin College

INTRODUCTION

I was recently involved in a study of the role of mathematics in the social sciences. Through working on that project I realized that mathematics plays a far more central role in our culture than I had been aware. I also began to formulate a Christian approach to mathematics, an entity whose existence I had previously doubted. The approach I have in mind is not uniquely Christian—that is, theists or secular thinkers who start from presuppositions different from those historically held by Christians could hold a very similar perspective. But it is consistent with historic Christianity and is quite different from the approaches that prevail in our discipline today.

The main feature of the approach I am suggesting is an emphasis on the centrality of context. The word "context" typically refers to the entire environment and setting that surrounds an entity. Thus this approach examines the settings in which mathematics is employed and asks what role mathematics plays (and ought to play) in those settings. For professional mathematicians and graduate students, mathematics is typically approached abstractly—completely separated from even the scientific questions that might have motivated it. Abstraction is a powerful tool and I do not want to devalue it. However, a Christian approach, I suggest, would view mathematics as much more than its abstract content.

Mathematicians have never been very successful at defining mathematics and I do not want to add yet another inadequate definition. Also I do not want to define mathematics operationally as "that which mathematicians do professionally" as many people do mathematics besides mathematicians. Rather I am going to *describe* mathematics somewhat imprecisely as a form of cognition characterized by such things as precise definition, careful reasoning, and abstraction. Viewed in this way, mathematical thinking is embedded in the minds of individual human beings all over the world, in all human cultures, and in history. Hence considering context means a lot more than merely considering applied mathematics. It means that certain questions need to be given a new status as essential to an understanding of mathematics; these questions currently interest many mathematicians and users of mathematics, but are typically marginalized from their "real" work. Some such questions are:

1. What can we say about God's purposes in giving us the capacity to do mathematics? How certain can we be of such assertions?

2. What is the role of mathematics in human thought and how does it differ from the roles of other modes of thought? What can be done with mathematical thinking that cannot be done other ways? What is it incapable of doing? (At the very least an answer to this question needs to address Kant's work on the nature of mathematical knowledge plus recent work on consciousness and reasoning by scholars like Dennett and Damasio.)

3. What have been the predominant views of the proper role of mathematics in human culture? Specifically, the Enlightenment view needs to be carefully addressed along with post-modern skepticism about the value of abstraction. How have mathematicians and mathe-

matics users tended to see this role? Can we as Christians say anything normative at this point?

4. What role has mathematics actually served in human cultures? Has it accomplished the Enlightenment hopes for it? Has it accomplished God's purposes?

5. Can the discoveries of mathematicians increase our understanding of spiritual truth? If so, how? (The concept of infinity certainly arises here.)

6. What is the nature of mathematical truth? How does this concept of truth compare to the concept of truth employed in the empirical sciences? In the humanities? To the Biblical concept? What problems arise when people confuse these concepts?

7. Ethical issues: How can mathematical models be misused? How can quantitative measurement and statistical analysis be misused? What is the responsibility of the mathematics community toward such (potential) misuses? What ethical principles ought to guide our thought in this area?

8. Values: What are the underlying values by which mathematicians assess the quality and importance of a piece of mathematics? How do these compare to Christian values?

9. What are the implications of our responses to questions 1–8 for how we ought to teach mathematics at all levels?

Thus this approach involves a concept of mathematics quite different from the abstract, formalist approaches that have dominated in the twentieth century. It is built on the premise that mathematics plays extremely important roles in human thought and culture and understanding these roles is a critical part of understanding the nature of mathematics. Since space is limited, I am going to concentrate primarily on questions one and three. My comments are introductory.

TWO THEORETICAL VIEWS OF THE ROLE OF MATHEMATICS IN CULTURE

First, let us consider the Enlightenment view. Newton and Leibniz are generally credited with developing the calculus around 1685 although their work built on many earlier advances. Using integration and Newton's formula for gravitation, the laws for planetary motion tediously worked about by Johannes Kepler around 85 years earlier from empirical data were easily derived. Thus, in the eyes of Newton's contemporaries, the question of humanity's place in the universe that had exercised the best minds for thousands of years had been answered by the discovery of some very simple laws. This discovery captured the imagination of that generation. One expression of the optimism of that time is Alexander Pope's famous epitaph written for Isaac Newton,

> *Nature and Nature's laws lay hid in night:*
> *God said, Let Newton be! and all was light.*

By the early 18th century, many thinkers began to seek such laws in other areas as well. This effort led to the "Enlightenment Project" or "modernism"—an effort to establish a common basis for human society based on careful observation (empirical science) and mathematics. Alasdair MacIntyre, a professional observer of the effects of the enlightenment, summarizes the initial aims of enlightenment thinkers this way [1]:

> *It was the shared belief of the protagonists of the Enlightenment ... that one and the same set of standards of truth and rationality—indeed of right conduct and adequate aesthetic judgment—was not only available to all human beings qua rational persons, but [these standards] were such that no human being qua rational person could deny their authority. The central project of the Enlightenment was to formulate and to apply these standards.*

It was widely believed that mathematics was, as Galileo expressed it, the alphabet of the universe. So mathematics was a critical part of the Enlightenment project. In fact, for some early Enlightenment thinkers, the world's order was viewed as God's own mathematical order, such that the rational study of this order was akin to studying God's own word or intentions. Thus the hope was that the Enlightenment project would yield a basis for society that would be non–controversial (unlike the many competing claims advanced by various religious ideologies) and would provide for peace, order, and human well–being. Although they have taken many different forms, ideas typical of the Enlightenment project have dominated Western universities until quite recently. Thus, for about three hundred years, mathematical and scientific thinking have been widely viewed as the two most critical methods for obtaining knowledge that will better human society. For instance, one of the main legacies of this movement today is "positive" social science—that is, social science based on careful observation, data collection and analysis, and attempts to infer scientific laws. The majority of social science research published today is based on this approach.

Since about 1960, a consensus has been building among many thinkers that the Enlightenment Project has failed and its assumptions ought to be rejected. Several philosophers of science have contributed to this movement, perhaps most notably Karl Popper [2] and Thomas Kuhn [3]. Subsequent to Kuhn, Popper, and others who thought similarly, the movement known as "post–modernism" has evolved. This is a loosely defined movement whose major tenet (if it can be said to have a tenet) is subjectivity. Stanley Grenz [4] has summarized four characteristics of post–modernism: post–individualism, post–rationalism, post–dualism, and post–noeticentrism. Post–individualism tends to emphasize the importance of community far more than the Enlightenment did. Post–rationalism emphasizes the limits of human reason and places a high value on non–rational modes of thought such as intuition. Post–dualism rejects the notion that a clear distinction can be made between mind and body and views abstraction with considerable suspicion. Post–noeticentrism rejects the notion that there exist abstract mathematical laws capable of describing human life analogous to the laws of physics. Hence, while the Enlightenment gave mathematics a well–defined and valuable place in human culture as one of the primary means available through which we can know truth and establish justice and order, post–modernism does not give it any explicitly acknowledged place at all. In fact, the primary characteristics of mathematics—precise expression, careful reasoning, the formulation of universal truths abstractly expressed—are viewed with considerable suspicion.

The consequence of the advance of post–modernism is that at present the Western academic world is suffering from a kind of intellectual schizophrenia. In both the natural and social sciences, most scholarship is still "positive"—that is, it is based on observation, collection of data, and theory formation. However, other scholars are approaching issues from a position that gives a much greater role to subjectivity. The Western academic world is struggling with two competing models—one that would make science and mathematics the foundation for culture and one that regards them as incapable of producing anything of the sort. Thus one of the principal characteristics of the academic world in our time is the division between these two dramatically different views of the proper role of mathematics and science in culture. And while it might seem that American culture is rapidly moving away from the Enlightenment perspective in the direction of post–modernism, an anchor is retarding that motion, namely technology. That is, our contemporary world economy is highly dependent on technology and technology is in turn highly dependent on mathematical and scientific ways of thinking. Thus there are deeply entrenched financial interests that will continue to resist the movement away from Enlightenment assumptions. All of this points out the urgent necessity of our thinking through the appropriate role of mathematical thought in culture from God's perspective.

TWO VIEWS FROM THE PERSPECTIVE OF SOCIAL SCIENCE

Before turning to Scripture, let's briefly examine two other perspectives. Raymond L. Wilder was a mathematician who applied concepts from anthropology to the study of mathematics as a cultural system [5]. Wilder saw mathematics as developed by a mathematical subculture of each culture in which it is found. Today it is found in very similar form in all developed cultures although there are variations of emphasis. He writes,

> *The uses of mathematics in the other sciences are generally of two kinds: (1) As a tool and (2) as a source of conceptual configurations. ... In recent times the "tool" uses of mathematics have increased enormously ... These are understandably important and have affected the course of mathematical evolution, especially through the demand made by the sciences for special tools. Not so well known are the uses cited in (2) regarding mathematics as a source of conceptual configurations. These need to be more generally recognized, since they call attention to the importance of core mathematics. Mathematics created in response to the request for a new conceptual tool is not, generally speaking, likely to prove fruitful so far as the evolution of mathematics is concerned. Rather it is ... "mathematics for mathematics sake," which is most likely to further the advance of mathematics and—it should never be forgotten—leads to conceptual structures that will cut a wide swath in future scientific thinking.*

He illustrates how core mathematics as a source of new concepts contributes to the broader culture:

> *It becomes more apparent, year by year, that the core of mathematics serves the general culture by producing new concepts whose future, in addition to their uses in mathematics proper, will be to move into the general culture, meeting needs unforeseen at present. ... Who, during the latter part of the 19th century and the first decade of the 20th, would have foreseen that the studies initiated by Boole, Frege, Russell and Whitehead, and Hilbert would soon generate notions such as recursiveness (Godel, Turing, etc.) which would serve as one of the basic notions of computer theory? Or that matrix theory, initiated by Cayley (ca. 1858) would turn out to be the precise tool needed by Heisenberg in 1925 for mathematical descriptions of quantum mechanics phenomena? Or that the theory of ana-*

> *lytic functions, involving complex quantities, would turn out to have widespread applications in physics and especially electrical phenomena? One could go on with the citing of such cases. The "moral" should, however, by now be clear: That the "pure" mathematics of today will be the applied mathematics of tomorrow.*

Thus from Wilder's perspective, the primary contribution of mathematics to culture is that it provides new ideas that alter culture in constructive ways that cannot be anticipated. Specifically, many of the major technological changes that have so altered human life in this century are built on ideas originating in mathematics.

Jacques Ellul, a French Christian writer, presents a different vision. Ellul has studied technology not primarily as technological artifacts, but as a way of thinking. [6, 7, 8] He investigates the notion of "technique," what we might call "algorithmic thinking;" that is, seeking to identify routinizable aspects of processes so that these can be optimized in terms of productivity and efficiency. So while technique is not explicitly mathematics, it shares many characteristics with mathematics—it emphasizes abstraction, the separation of idealized processes from context, careful representation, the study of patterns rather than unique phenomena, and optimization.

Ellul's critique of technique is extensive and complex, but I am going to risk oversimplifying by summarizing it. Ellul argues that (at least in the 1950s and 1960s when he first began to write) technique had become the predominant thought mode in Western civilization, most notably in the United States. His criticism is that the only values technique recognizes are efficiency and productivity and even those are implicit. Thus by explicitly excluding matters of value, norm, and purpose, technique implicitly elevates productivity and efficiency to ultimate values. Also it weakens thinking about ends and processes by leading people to dismiss any thinking that is not reducible to formalizable logic. Thus the Enlightenment effort to be mathematical and objective and hence to exclude values, norms, and purposes from the search for truth led to a society in which careful thought about such matters was neglected and productivity and efficiency unconsciously assumed the role of ultimate values.

In short, Wilder's view is of a benign mathematics that creatively generates new ideas that benefit society, while Ellul's vision is of mathematical–type thinking run amok—a juggernaut that is destroying much that is good and valuable in human culture.

GOD'S PURPOSES

"Teleology" is the name traditionally given to the study of purposes. For instance, Aristotle, in his writing on causation, spoke of "efficient causes"—the mechanism by which a change is wrought—and "final causes"—the use or purpose of that change. But as thinkers influenced by the Enlightenment increasingly sought mechanistic explanations for phenomena, the concept of teleology or final causes fell out of favor. Thus today, in the natural science community, teleological explanations are typically seen as inappropriate. However, the Enlightenment era seems to be at an end and, as Ellul has demonstrated, the neglect of questions of purpose has had some serious negative repercussions. Also this article is examining mathematics from a Christian perspective. So some reflection on God's purposes for mathematics is appropriate here.

The concept that God is purposeful is abundantly presented in Scripture and no orthodox Christian tradition has ever questioned it. But God's purposes are only knowable in so far as He chooses to reveal them. So while Scripture never presents God as saying "My purpose for mathematics is ... ", we can infer a great deal from those things He has chosen to reveal. Scripture presents God as expressing several purposes among them saving human beings from sin and its consequences, revealing His nature, and blessing His people. My focus here will be on the latter although I believe mathematics can play a valuable role in revealing aspects of God's nature as well.

The Biblical notion of blessing is perhaps best captured through the concept of "shalom"—a state of peace, harmony with God and other people, fruitfulness, and well–being. Humanity's creational role in this state of global shalom is stated in Genesis 1:28, the passage that Reformed thinkers are fond of calling "the cultural mandate:"

> *Be fruitful and increase, fill the earth and subdue it, rule over the fish of the sea, the birds of heaven, and every living thing that moves on the earth.*

Note that the commands to subdue and to rule are addressed to the entire human community as a shared stewardship. But God does not give commands without providing the means for carrying them out. It seems to me that mathematical thinking fulfills at least two unique roles in "subduing and ruling" played by no other human capability: (1) Mathematics enhances communication by providing univocal definitions and rules of inference that enable people to understand concepts and conclusions in the same way—that is, mathematics makes it possible to carry out those aspects of this *shared* stewardship that require a very high level of common understanding. Put differently, in some of the arts, the focus is on the uniqueness of the individual expression. Mathematics is far more communal—common understanding of concepts and shared rules of inference are essential. (2) Mathematics enables certain types of analysis to be conducted that could not be carried out in other ways. That is, mathematics provides the ability to represent complex ideas and to deduce implications of those ideas that our minds unaided by mathematics could not infer. Also, mathematics enables us to represent plans for alternative realities that do not presently exist, explore their consequences, compare alternative plans, and make decisions. Such matters are often very complex and the only known means to investigate them depend on mathematics. Mathematics, then, is more than a source of new ideas arising at the frontiers of our understanding as Wilder suggests—it is a communication medium and analytic tool providing unique capabilities available to everyone.

Some examples of how mathematics has actually functioned in culture can illustrate these ideas. A blueprint is an elementary example of these communication and analysis roles. Its cognitive characteristics are typical of mathematics—symbolic representation, abstraction, and precise quantitative measurement. But it enables an architect, an owner, and a team of builders all to understand the plans for a building in precisely the same way. Furthermore, a blueprint enables inferences such as "These two doors could hit if opened simultaneously" that might not have been anticipated if construction had proceeded without a written plan. There are many mathematically more sophisticated examples, but the underlying principle remains the same. For example, on July 1, 1940, the Tacoma Narrows Bridge outside Seattle, Washington was opened; on November 7, it collapsed. On the day of its collapse, a strong wind was blowing up the Narrows. It caused the bridge to vibrate at a resonant frequency, and over a few hours the bridge literally tore itself apart at the cost of millions of dollars and a great inconvenience to many people. Fortunately, no lives were lost. But the failure of the bridge was an expensive way to uncover a design flaw.

Today such a failure is much less likely as mathematical models of factors such as stress and strain relationships, resonance, and turbulence are better developed, widely understood, and have been incorporated into computer simulations. That is, engineers can design a "virtual bridge" first, test the design, and even create and compare alternate realities for the bridge, all without driving a single pile or placing a girder. That is, mathematics allows us to represent reality and manipulate the representations rather than the reality itself. Logical reasoning enables us to explore the consequences of the assumptions we build into representations so we can anticipate the results of our actions. Such a capability is critical for the fulfillment of our stewardly role and mathematics is often the best provider of that capability.

But such capabilities are not restricted to the spheres of natural science and technology. For example, in 1950, Kenneth Arrow was investigating voting methods. He set down a small set of reasonable "fairness" criteria that most people agree a voting method ought to possess. He then proved a result that is known as his "impossibility theorem," namely that no voting system possessing all of the criteria is possible. This is a phenomenally important result in that it tells us that there are *a priori* limits on the *social* structures we can build. Thinkers have reflected on concepts of justice and fairness for millennia, but it was only when fairness was represented mathematically that the logical impossibility of a voting system satisfying these criteria was discovered. Furthermore, the various proofs of Arrow's Theorem give insight into why these limits exist.

In summary then, mathematics is a gift of God that helps to enable us to carry out His purposes for human life by enriching human communication and analysis in a unique way. Several properties of mathematics enable it to do this:

- Mathematics is quantitative (although it is not only quantitative). Numerical measurement enables finer distinctions than can be made by any other means of using language.
- Mathematical representation provides a means for transcending individual subjectivity. For instance, if an object weighs 30 pounds, it may *feel* heavy to one person and light to another. But both persons share a common standard of weight to which the object is being compared. So when one says "It weighs thirty pounds," information is communicated that does not depend on either person's subjective experience. Other uses of language do not provide this capability.
- Univocal definition and symbolic notation provide for common understanding.
- Rules of inference provide a powerful tool that is widely shared and accepted for exploring consequences of assumptions. Thus they enable conclusions that command broad agreement.

A CHRISTIAN VIEW OF THE ROLE OF MATHEMATICS IN CULTURE

Given this perspective on God's purposes, we can sketch a few features of a Christian view of the role of mathematics in culture: Mathematics is a gift of God given for our blessing, specifically, to help us to carry out the stewardship of this world He has entrusted to our care. Like all of His gifts, it ought to be received gratefully and enjoyed. It enables us to explore the abstract relationships among ideas. It enables us to represent reality, to understand it, and to modify it in a stewardly manner. In fact, it enables us to represent reality well enough that we can artificially create alternate realities and can safely explore the consequences of implementing them. It frees our minds to explore ideas that may go far beyond any concrete realities that we have actually experienced.

But mathematics possesses limits: It is hard work to formulate ideas precisely and to carry out logical arguments (unless they are very elementary) and it is hard work to understand someone else's precisely formulated idea. Thus mathematical language cannot provide the speed and effectiveness of communication that metaphor can provide. It cannot evoke emotions such as empathy and indignation as stories can do. Even analysis can proceed another way: It can often be conducted more efficiently and effectively by case study—that is, comparing the current situation to another that is well understood. Mathematics is not suitable for dealing with situations in which the principal features are characterized by a great deal of ambiguity. It is not capable of doing what some early Enlightenment thinkers had hoped—even when combined with the best scientific observations, it can never be a source of values, ethics, or understanding of the nature of God. And, when used in modeling, it can be applied as effectively with false or unethical assumptions as with true and ethical ones.

In summary, then, considering God's purposes yields a perspective on mathematics distinct from both the Enlightenment and post–modernism. That is, by making mathematical and empirical investigation the sole legitimate sources of truth, the Enlightenment made mathematics an idol. Post–modern thought tends to go to the other extreme and reject abstraction entirely thus neglecting a good and valuable gift of God. Rather, an attempt to examine the role of mathematics in culture from the perspective of God's purposes leads to an affirmation of a vital and unique role for mathematics, but also to a recognition that mathematics has limits and must be used in consort with other modes of thinking and other sources of knowledge and principles. Interestingly, it also leads to the conclusion that both Wilder and Ellul are correct. That is, mathematics is capable of providing both great blessings and great harm. In fact, Ellul's assertions can be seen as a powerful illustration of the dangers of applying abstract, mathematical–type reasoning without regard for a context that provides meaning, ethics, and values.

CONCLUSIONS

What principles ought to characterize mathematics so that it can enable us to fulfill God's purposes? I suggest that we focus on the nature of the mathematical community, rather than on mathematical content. In advocating this direction of investigation, I recognize that my suggestion will be unpopular with many mathematicians. Mathematicians are trained to think about mathematical content, not the role of mathematics in culture or the nature of their professional community. For instance, I recently read the catalogs for the top ten graduate mathematics programs in the United States.[1] None offer a graduate level course in the history of mathematics and only one (Stanford) offers a course in the philosophy of mathematics. And Stanford's philosophy of mathematics course focuses on questions arising in areas such as epistemology, ontology, and truth theory, not on issues involving culture. Furthermore, in my review of several history of mathematics textbooks, I have yet to find evidence of critical thinking in the sense of scholars going beyond the question of what the role of mathematics in cultures *has been* to ask what it *ought to have been.* Rather the history of mathematics is typically presented triumphalistically as a parade of great achievements. In contrast, it is hard to imagine military or political history presented with so little

1. Berkeley, Princeton, MIT, Harvard, University of Chicago, Stanford, Yale, NYU, University of Michigan, Columbia

critique. Thus I am asking for a kind of critical thinking with which the mathematics community is somewhat unfamiliar. But it seems to me that this is a crucial point at which Christian thought has something uniquely valuable to offer.

I would like to set down a collection of normative principles in a somewhat axiomatic fashion that, it seems to me, would characterize a mathematical community functioning as God intends.[2] At this point I will simply present the principles without application. I will follow with a few brief remarks about how they might be applied.

Our main conclusion up to this point is that mathematics is a gift of God that plays a unique role in enabling human beings to carry out their stewardly mandate. The norms follow from this mandate:

1. Openness: Mathematicians tend to think of the "mathematics community" as those who teach or do research in mathematics. But there is also a broad "mathematics user community" consisting of many people who use mathematics in a significant way in their scholarship and practice. Communication within and between these communities ought to frequent and unimpeded by factors such as status or pride.
2. Stewardship: The community would see itself as the custodian of a very valuable gift. As such it would seek to further the understanding and applicability of mathematics through research and teaching and would be faithful to the nature of mathematics in doing so. It would also serve in a custodial role for the larger culture by systematically and publicly critiquing uses and misuses of mathematical ideas and methods.
3. Humility: The community would value the gift of mathematics for which it is steward, but would also recognize its limitations and guard against those who would ignore them.
4. Respect: Along with humility about the limitations of mathematics, the community would be characterized by a high degree of respect for other gifts, especially other modes of thought. It would actively seek to understand what classes of problems and situations it is uniquely suited for and what problems it is inappropriate for. It would actively seek symbiotic relationships with other disciplines.
5. Accountability: The community should recognize that along with its responsibility to serve as custodian for the gift of mathematics, the larger society has the right to hold the mathematics and mathematics user communities accountable for proper exercise of that stewardship. For instance, in our time we are experiencing an unprecedented "mathematization of society." The larger society has a right to hold the two communities responsible to monitor the progress of that movement, to be alert to dangers resulting from either inadvertent or deliberate misuses, and to develop channels by which it can make such dangers known.
6. Service: The community should recognize that's its role is one of service to others not self–indulgence. Thus the community would actively seek ways to serve wherever soci-

2. An answer to the question "How has the fall affected mathematics?" is implicit in the approach taken here. Sinfulness is fundamentally a characteristic of persons and communities and some aspects of what they do. Mathematics per se could no more be sinful than could any other form of cognition, for instance, metaphor. But mathematicians are sinful and can easily violate these norms, just as language can be used for evil ends.

etal needs are found that would lend themselves to mathematical analysis. But it would also balance such intentional service with a recognition that the most revolutionary advances in mathematics were made by people seeking truth not by people attempting to be socially useful.

7. Critical reflection: Communities closely related to the mathematics community (for example, the operations research community and the computing community) regularly engage in critical reflection on their role on society, the effectiveness of their contributions, and similar questions through conferences and their flagship journals. The mathematics community ought also to be conscious of its responsibilities in culture and should create forums by means of which it can actively engage in constructive reflection so as to maintain its faithfulness to its mandate.

It seems clear that the mathematics community has fulfilled many aspects of these norms. But it's also not hard to see some general ways that faithfulness to these norms would alter the practices of the mathematics community, although it seems to me premature to be detailed until principles such as these have enjoyed wider discussion. Some general conclusions that I draw are: There should be no status hierarchy based on the "purity" of one's mathematics. Mathematicians should more actively engage with scholars in other disciplines that use mathematical thinking and seek to strengthen such scholars by regularly offering constructive critiques of their uses of mathematics. Mathematicians should more actively seek to recognize and discuss the limits of their discipline and the ways mathematical thinking might interface with other modes of thought. The mathematics community should honor and reward those who use mathematics in significant forms of service equally with those who solve difficult and profound mathematical problems; it should seek opportunities for such service. The graduate training of mathematicians should be broader and less narrowly focused only on preparation for research. The community ought to find ways to engage more effectively in critical reflection than it presently has created.

ACKNOWLEDGEMENTS

I would like to thank the Calvin Center for Christian Scholarship and Calvin College for the financial support that made this paper possible. I would also like to thank the mathematics faculty of Calvin College for some helpful discussions of an earlier draft. And I would like to thank Ronald Freiwald for his helpful critique.

REFERENCES

1. as quoted by Richard John Neuhaus, "Joshing Richard Rorty," *First Things* 1:8, December 1990, 14–24
2. Popper, Karl, *Popper Selections*, ed. by David Miller, Princeton Univ. press, Princeton, NJ, 1985
3. Kuhn, Thomas, *The Structure of Scientific Revolutions*, Univ. of Chicago Press, Chicago, 1962
4. Grenz, Stanley J., *A Primer on Post–Modernism*, Wm. B. Eerdmans Publishing Company, Grand Rapids, Michigan, 1996
5. Wilder, Raymond L., *Mathematics as a Cultural System*, Pergamon Press, Oxford, 1981
6. Ellul, Jacques, *The Technological Society*, Alfred P. Knopf, New York, 1964
7. Ellul, Jacques, *The Technological System*, Continuum, New York, 1980
8. Ellul, Jacques, *The Technological Bluff*, Wm. B. Eerdmans Publishing Company, Grand Rapids, Michigan, 1990