2006-85: JUSTICE AND HUMILITY IN TECHNOLOGY DESIGN

Steven VanderLeest, Calvin College

Steven H. VanderLeest is a Professor of Engineering at Calvin College. He has an M.S.E.E. from Michigan Tech. U. (1992) and Ph.D. from the U of Illinois at Urbana-Champaign (1995). He received a “Who’s Who Among America’s Teachers” Award in 2004 and 2005 and was director of a FIPSE grant “Building IT Fluency into a Liberal Arts Core Curriculum.” His research includes responsible technology and software partitioned OS.

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1 Abstract

Engineering design requires choosing between various design alternatives, weighing each option based on technical design criteria. Broader criteria have been suggested that encompass the cultural, historical, and philosophical contexts in which the new technology becomes embedded. These criteria, called design norms, can only be applied effectively by engineers with a strong liberal education. This paper examines two design norms in some detail. The first norm, justice, has been noted in the past as an important criterion for design decisions, but not to sufficient depth to provide practical design insights. Design for justice requires consideration of all stakeholders of a design. Technological designs can intrinsically lead to injustice, for example, if they disrespect stakeholders or cause discriminatory inequities. The second norm explored in this paper, humility, has typically been considered a good quality of the engineer, but not often applied to technology. The implications of using humility as a design criterion might include more emphasis on reliability, user feedback, and more broadly, a recognition of human limitations and fallibility.

2 Introduction

Traditional engineering education teaches students how to use technical principles to make engineering decisions. However, the EC2000 criteria encourage broader engineering education that includes non-technical, contextual disciplines. Unfortunately engineering students often see courses in the humanities as a hurdle to get past, and revert to using narrow technical approaches to solving problems and producing technology. Transferring knowledge in one domain (liberal arts) to another (engineering) is difficult.[1] One approach that helps students integrate their contextual, liberal arts education with their technical learning is the use of design norms. This paper explores two norms, or guidelines, for technology design: justice and humility. We begin by looking briefly at the design process and defining the design norm in Section 3. The following section explores the parallel idea of use norms. Section 5 reviews a number of ways to define justice and concludes with the application of justice as a technology design norm. Similarly, Section 6 applies humility as a norm.

3 Design Norms

When designing a product, the engineer works iteratively through a step-by-step process:

- Specification: Define the problem. Clarify the requirements of the project.
- Ideation: Identify alternative solutions to the problem, often by brainstorming a variety of ideas.
- Prioritization: Identify decision criteria to rate the various solutions, such as cost or weight.
- Decision: Apply the decision criteria to decide between the alternatives, often using a decision matrix.
- Implementation: Work out the details of implementing the chosen solution.

Frequently the knowledge and ideas generated during one step in the process leads back to earlier steps for refinement and modification. Thus, the design process is more iterative than linear. This paper focuses on the prioritization step, where the engineers identify the decision criteria, sometimes called the design criteria. The criteria used to rate the alternative solutions usually include cost and may include speed, power, time to market, or reliability, for example.

In order to systematize the decision so that the trade-offs between various alternative solutions are explicit and clearly identified, engineers often use a simple organizational device called a decision matrix. The matrix is a table with a row for each alternative solution and a column for each design criteria. The cells of the table contain ratings that estimate how well each alternative fulfills each of the criteria. Because the criteria are rarely equal in importance, engineers use a numerical priority to weight their ratings. The sum of the scores in a row indicates the overall desirability of the associated alternative. Table 1 provides an example matrix. The two alternative solutions are evaluated against three weighted design criteria, resulting in the selection of the second alternative. This approach assumes that all the criteria can be compared in a linear fashion (i.e., the whole is equal to the sum of its parts). Criteria that are less objective, and thus harder to quantify, may not fit this assumption as well[2]. This is important because the design norms fall into this category.

Table 1: Example Design Matrix

Weight:	40	25	35		
Criteria:	Cost	Weight	Time to market	Total	
Solution 1	35	21	25	81	
Solution 2	30	24	32	86	←Winner

Because they are not technical in nature, some of the most important criteria in making technology decisions are sometimes inadequately emphasized. The book *Responsible Technology* introduced a set of technology design norms that emphasize contextual aspects of technology to balance more narrowly focused technical criteria. The proposed norms include cultural appropriateness, stewardship, trust, open communication, and others[3]. Norms are guidelines or principles that guide behavior – in this case, guidelines for holistic design of technology. Unless the engineer recognizes the context in which technology is placed, she will not understand the full implications of embedding a specific technological product with a cultural and societal framework. Design norms are powerful tools for explicitly recognizing the context of technology during the design process. They put the designer in the shoes of the user. Furthermore, they force the designer to consider all stakeholders in a design, not just those paying for it.

The norms also underscore the non-neutrality of technology. Technology is biased – its design intrinsically steers the user toward certain uses and away from others. Although the designer may have one particular use in mind, the technology is biased towards other uses as well, some similar to the intended use, but sometimes quite dissimilar and perhaps unanticipated. If an engineer does not foresee an obvious consequence of a product that results in harm to the user that he could have prevented, he may be legally liable for that harm.

Langdon Winner has famously described one example of intentional bias in the story of how Robert Moses designed bridges over roadways leading to beaches and parks in New York. He selected the bridge heights so that a bus could not pass underneath. This effectively segregated the lower income black population from reaching the beach.[4] While Moses was intentional in incorporating this bias, more often, the designer does not intentionally build in bias.

Nevertheless, it is intrinsically present; the designer cannot help but design from within his own worldview – from the basis of his own historical, social context. Even if an engineer does not intentionally bias a design to cause an injustice, if she designs a low bridge, ignorant of the impact on justice, she is still guilty of technological/social negligence.

4 Use Norms

In the previous section, I suggested that engineers should consider design norms as guides to appropriate and responsible design of technology that take into account all stakeholders and recognizes broader accountability. In this section, I explore guidelines for users of technology, which we could call "use norms."

The best technology allows the user to participate in the creative process. To use technology well is to interpret it, to extend it. Technology should be transparent enough that the user understands how it works and can explore new uses for it. Users can be creative with software that allows user extensions, such as web browsers that allow and encourage third-party plug-ins, or with software applications that provide scripting or macro tools. Some children's toys allow creative extensions and exploration, such as Erector® sets or Lego® Mindstorm robot kits.

Norms for use closely parallel norms for design. Choosing the technology to use in solving a particular problem is not a passive exercise, but is itself a design problem. For example, we may face the problem of hammering a nail in the wall in order to hang a picture. As we look around the room for an appropriate tool, we might wish for a hammer. If a hammer is not available, we improvise, using a rock or a hard-soled shoe perhaps. Thus, we have identified the problem, identified alternative solutions, and then selected the best solution among the alternatives based on some criteria. In this case, those criteria were perhaps immediate availability, material properties such as the hardness of the striking surface, physical form and dimensions so that we can hold and swing the tool easily, and so forth. Everyone that uses technology is also designing technology – particularly when one improvises a tool beyond the designer's anticipated use.

On the other hand, perhaps it is best to let the experts tell us all exactly how to use our technology. Some would argue that it is dangerous and maybe even foolhardy to let ordinary people modify and change technology. If one is not an engineer – not an expert – then one should not be tinkering around with technology. Non-engineers may not understand the implications of the changes they make and thus may introduce new hazards to themselves and others. The engineer who designs a product has a responsibility to design it in such a way that users cannot hurt themselves, and thus must design products that are not easily modified or enhanced. Just as doctors are the experts in dispensing medicine and the patient should never deviate from the doctor's precise instructions regarding that medicine, so too engineers are the experts in designing technology and the user should never deviate from the engineer's precise instructions regarding those products.

However, this is too stark a division. The line between the expert and the novice is not so clear and the gap between them is not so large, for at least two reasons. First, engineers themselves do not always anticipate all the ways a product might hurt the user. Despite their technical expertise, they sometimes miss important details, perhaps because they are too close to the details, or perhaps because they do not empathize enough with the user. As Thamus chides Theuth in Plato's Paedrus, "…the parent or inventor of an art is not always the best judge of the utility or inutility of his own inventions to the users of them"[5] Good engineering requires a team approach to help tease out all the important facets and implications of design decisions. Often these teams include not only engineers, scientists, and other technical experts, but also financial analysts, artists, marketing and sales experts, managers, and others. Although they do not have technical expertise, they nevertheless have viewpoints important to the design. Such diverse background provides the divergent thinking that is necessary for robust design. Good engineering also requires a strong liberal arts background for the designers so that they can see the broader context that brings out the facets and implications of the design decisions. Engineers who have studied history will more deeply understand the historical thread that ties a new technology to existing products and gain insight into how that thread will develop further with their addition. Engineers who have studied music will have developed an aesthetic sense that provides for taste in technology as well as art. Engineers who have studied literature will have better insight into human nature – our triumphs and failings – and from this will gain insight into how technology can amplify our power to do good or evil.

Second, all of us are engineers to some extent. Part of what makes us human is our ability to create tools to solve problems. Our humanity is defined in part as *homo faber*, man the maker. Karl Marx noted this quality in his *Capital*, referring to a well-known turn of phrase attrib uted to Benjamin Franklin: "The use and fabrication of instruments of labour, although existing in the germ among certain species of animals, is specifically characteristic of the human labour-process, and Franklin therefore defines man as a tool-making animal."[6] If our identity as humans is founded in part on our ability to create and fabricate tools, then we cannot afford to leave this important human activity to a select group. Music is also an important element of our human identity, as Robert Fulghum noted: "Never forget that music is too important to be left entirely in the hands of professionals." As it is for music, so it is for technology. To be fully human is to indulge the creative spirit, not only in art such as music, but also in engineering and design. Abraham Maslow, in describing his hierarchy of human needs, notes that human self-actualization requires that one act out one's identity: "A musician must make music, an artist must paint, a poet must write, if he is to be ultimately at peace with himself. What a man can be, he must be."[7]

To illustrate use norms, I will briefly consider the norms of cultural appropriateness, stewardship, and caring. *Cultural appropriateness* ensures that the solution fits the problem – carefully defining what is really needed so that one can also carefully choose the technology to meet those needs. Since we can often identify multiple solutions to the same problem, choosing one that best fits the culture in which it will be embedded is an important goal not only for design, but also for use. In selecting technology for purchase, one should consider how well it fits personality, lifestyle, and relationships. *Stewardship* encourages selection of a solution that uses the least resources, especially emphasizing reduction in the use of non-renewable or scarce resources. This is not merely a matter of choosing the least expensive product. It means choosing the product with the minimum total cost of ownership. It also requires carefully balancing the cost of resources against the benefit. For example, for a conference presentation, one might plan on giving a PowerPoint presentation, requiring a laptop. However, as a backup, one might make transparencies for use on an overhead projector, in case there is a problem with the laptop. Such presentation insurance requires extra time and resources. The presenter must carefully judge whether the significance of the presentation warrants the extra resource use. Norms guide us to consider carefully the effects of technology on all stakeholders. For example, the use norm of *caring* might dictate when a user decides to use technology. Using a loud snow blower in the early morning or late in the evening violates the norm of caring if it wakes the neighbors.

5 Justice as a Design Norm

Justice is a fundamental principle of society. When injustice occurs people cry out for it to be righted. Lack of justice can result in violence and war: "if you want peace, work for justice."[8] Both Monsma[9] and Schuurman[10] have suggested justice as a design norm. Technology injustice arises from unintentional features of poorly thought-out designs. Justice in technology is more likely when the design is intentional and carefully considered within its broad context. Before looking at the relationship of justice and technology in detail, let us first look at some definitions of justice.

5.1 Justice Defined as Retribution

What is justice? For many, it is retribution. Seeing justice done means making one pay for a wrong they have committed. Serving justice may even satisfy a desire for revenge. Society may use punishment as a means of rehabilitation or deterrence, but it also uses it as a means of vengeance, i.e., retribution. The "long arm of the law" refers to the far reach and the strong intent of society to find and punish those that violate the established laws. Justice defined as retribution requires that the punishment must fit the crime – it must be equal in severity to the harm done.

5.2 Justice Defined as Respect

The authors of the book *Responsible Technology* define justice in terms of giving each what they are due: "…all persons are to be given what is rightfully due them...."[11] Applying this idea to technology, they asks engineers to apply this question to their products: "will this technology give due respect to fellow human beings, other cultures, and the natural [world]?" Unfortunately, the book describes the notion of justice so broadly that it is difficult to tell what is not included. The authors provide examples of injustice that include dehumanizing the workplace, displacing workers, destabilizing the traditional family, disrupting cultural traditions, causing the extinction of plant or animal species, and wasting resources. All undesirable outcomes of technology, to be sure, but as a list, not very telling for understanding what the demands of justice might be. Nevertheless, the ideas of justice as respect and giving each their due are useful and important. Definitions that include virtually everything are not very useful, thus it would be helpful to narrow the term a bit. For example, the norm of stewardship might better be used to encompass the idea of using natural resources wisely. The norm of caring would be a more appropriate reason to avoid dehumanizing the workplace. We could still consider displacement of workers or disruption of family to be a matter primarily of justice if we consider stable employment or stable families to be a fundamental human right, or if we consider the underlying problem is that of inequity, or unfair treatment.

If justice is each one getting what they deserve (whether reward or punishment), then the problem of justice is a problem of defining "just deserts." It follows that we must explore *why* one deserves and *what* one deserves. First consider why – on what basis does one deserve something? Must one earn a reward (such as a resource) or can you acquire it based on some inherent quality (such as by inheritance or because it is a basic human right)? Must one earn a punishment, or can you receive it based on some inherent quality? It is hard to imagine that punishment could be doled out justly for reasons other than one's own actions. If punishment is only shared if it is earned, then should not justice also require that reward be shared only if it is earned? I suggest that this is indeed the case for non-necessities. Now consider *what* is due each person. What does each person have a right to demand? May each person demand an equal share? Share of which resources? Perhaps people have a right not only to shares of material resources, but also to immaterial things like respect, dignity, and freedom. There is wide agreement about basic human rights due each person (e.g., right to free speech, right to assemble, right to religious freedom) but it is harder to gain consensus on higher order rights, such as the right to meaningful work or the right to pursue happiness and self-actualization. I suggest that in addition to basic human rights, we should consider basic resources necessary to life as items that must be equally distributed, e.g., clean drinking water or security. Resources that are not necessities (we might call them luxuries) could be unequally distributed without necessarily causing an injustice, e.g., thy must be earned.

5.3 Justice Defined as Social Equity

In his book *A Theory of Justice*, John Rawls promotes the idea of justice as fairness. Although Rawls could have explored the origin of justice – considering why we believe we should be just in our dealings with others, instead he posits a thought experiment that reveals what the form of those just dealings ought to be. Imagine a group of humans that were to decide on principles of justice for all. The group is in an "original position," kept behind a "veil of ignorance" which prevents them from knowing ahead of time what their own particular place and position in society would be, i.e., they do not know the social class of their family, what their own innate abilities will be, what there prospects will be, and so forth. Rawls believes that principles of justice developed in such a state will be the fairest, most equitable principles possible. He assumes that people in this original position would choose principles that resulted in the best situation with the least inequity, since no one would know *a priori* which position they would take up. Thus, he supposes that they will adopt a so-called "maximin" approach, which considers the worst-case scenario in which one might find one self after adopting a set of principles. That is, Rawls suggests that this group of humans would select principles to maximize the prospects of the worst off in society. He sums up his ideas by saying: "All social values – liberty and opportunity, income and wealth, and the bases of self-respect – are to be distributed equally unless an unequal distribution of any, or all, of these values is to everyone's advantage."[12]

Rawls addresses a number of the possible objections to his theory. One difficulty arises because decisions regarding justice are dictated by the welfare of the least well off. This is the case no matter the scale of the difference: "Yet it seems extraordinary that the justice of increasing the expectations of the better placed by a billion dollars, say, should turn on whether the prospects of the least favored increase or decrease by a penny."[13] Rawls dismisses this difficulty by stating that it will not actually occur: "The possibilities which the objection envisages cannot arise in real cases; the feasible set is so restricted that they are excluded."[14] Rawls assumes a closed, self-sufficient society, but with globalization effects (partly caused by technology), we must consider society to stretch across the globe. In today's world, the justice of a billion dollar difference in an ultra-wealthy western executive's fortune really could turn on the difference of merely pennies for developing-world subsistence farmers.[15]

Robert Nozick notes at least two difficulties in Rawls' theory of justice. First, he questions Rawls' assumption that resources are "up for grabs" and should be distributed. This is problematic because most resources are currently owned by someone. Nozick, in his work on Entitlement Theory, makes the plausible claim that any situation that arises by just exchanges starting from an originally just distribution will also be just[16]. He thus proposes that principles of justice should cover how one justly acquires resources not yet owned, and how one justly exchanges or transfers resources once owned. Secondly, Nozick suggests that Rawls does not properly recognize the autonomy of the individual. He claims that the individual is sacrosanct, and has rights that can only be limited at the boundary of the rights of another individual[17]. In fact, Rawls does describe the goal of extensive liberty for each in just these terms. However, Rawls' suggestion that one's resources might be distributed to others appears to violate the individual's rights, in the eyes of Nozick[18]. He thus proposes his own thought experiment. Suppose a famous basketball player agrees to play for a certain team, but only if the team pays him a bonus that amounts to a surcharge on each ticket sold. The team agrees because this big star will draw in a big crowd. Each person buying a ticket gladly pays the small surcharge because each wants to see the star play. If everyone started out with a just share of resources, then after the game (when the resources are now unevenly distributed), would we claim that the big star has unjustly gained resources? Nozick claims that everyone got what he or she deserved, i.e., justice was served. Each attendee to the game wished to exchange their resources for the chance to see the star play. Does justice prevent individuals from using their own resources because this would result in an unequal distribution? Yet, this is apparently the paradoxical conclusion one would draw from Rawls.

Bob Goudzwaard does not believe justice requires equality of resources. Rather, he allows for differences among people as a natural and expected situation. Nevertheless, people are to be equally valued intrinsically. Resources belong to the community (though not necessarily in equal quantity) in order to serve the community and bring solidarity to the community members. "Men created with different capacities, talents, needs, insights, and potential skills are equally obligated to interact. And that means an obligation to maintain solidarity, for that is the purpose of economic life as a whole."[19]

5.4 Applying Justice to Technology

Technology has a large role to play in justice as retribution. Modern law enforcement is replete with technology, such as data mining software, pepper spray, face recognition software, video surveillance, handcuffs, ballistics tests, fingerprinting, metal detectors, and so forth. However, these technologies used to lengthen the arm of the law must also be the subject of critical evaluation in the light of justice. If justice is truly blind (treating people equally without regard to color of skin, gender, etc.), then technology used to carry out justice must also be blind. In honoring justice, we must root out any bias in law enforcement technology that implicates based not on relationship to the crime, but based on innate characteristics such as race or gender.

When considering justice as social equity, if technology is not neutral, if it is biased towards some uses, then the design of technology can cause injustice. For example, computer technology seems to be biased towards Caucasians (the so called "digital divide"), even when controlling for education and income.[20] While there may be an array of reasons for such differences, we must consider that the design itself may be intrinsically unjust. The problem is particularly poignant because computers (and more generally, access to information infrastructure) are becoming essential for full participation in modern society. If there are structural features of an essential technology that cause unjust distributions, then the technology is unjust and should be modified. There have been cases where designs were intentionally biased towards an injustice, such as sizing a bridge to a park so that buses could not pass, thus discriminating against lower-income would-be park visitors. However, it is probably more often the case that the engineer unintentionally introduces injustice into a design. A better understanding of the needs of all stakeholders and a deeper comprehension of the context should be a good antidote to such oversights, allowing for more just design through more intentional design. Just as engineers can design technology to cause injustice (perhaps unintentionally), they can design it to serve the needs of justice in situations where inequity occurs. For example, medical devices such as hearing aids or laser eye surgery can improve damaged senses. Mass transportation can level the playing field for those seeking employment who do not own their own vehicle.

Is the engineer always in a position to make critical decisions that affect justice? No, not always. However, engineers have widening circles of influence, so even when they do not have direct authority to make a decision, they can affect the decision positively. Engineers have personal influence on their immediate colleagues and co-workers. They may have a voice within their institution. They may even have a broader social influence, with their voices heard through journal papers, on standards committees, and so forth. Technological justice depends on the moral decisions of the technology user just as much as it depends on the designer. In market-driven economies, the buyer decisions drive the direction of the entire economy. The seller cannot easily steer the market, but must respond to market demands. If buyers collectively demand products that inherently cause injustice, the seller cannot easily dissuade them. Buyers can and should collectively decide that justice is important, pronouncing their decision through their buying habits and through mutually agreed upon constraints on the system (government regulation).

6 Humility as a Design Norm

Humility is the opposite of pride. It is to be modest. It is to see one's accomplishments and abilities in a sober and critical light. Humble people avoid being too flashy or too showy. In the case of technology, reliable, robust, transparent products arise from a design process approached with personal and professional humility. Humility takes courage. Standing up and taking responsibility for a mistake requires internal fortitude – it takes guts! Robert Furey sees humility and pride not as much as opposites, but as necessary complements to each other: "Humility and pride compose a dialectic; each concept gives the other meaning. Without humility, pride becomes arrogance and conceit. Without pride, humility becomes passivity and complacency."[21]

Personal humility is important for an engineering professional. We can find expectations for personal behavior related to humility in many engineering codes of ethics. For example, most engineering codes of ethics indicate that engineers must act within their area of competence and honestly indicate any limitations in their expertise. The Institute of Electrical and Electronics Engineers (IEEE) code of ethics indicates that members agree "to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations."[22] Many of the codes also stress the importance of avoiding claiming someone else's work as one's own. For example, the National Society of Professional Engineers (NSPE) code of ethics calls engineers to "give credit for engineering work to those to whom credit is due."[23] (This code also relates to the norm of justice because it seeks fairness.)

Not only do the codes provide guidelines for personal behavior that relate to humility, but they also provide some principles that relate closely to the technology design process itself. Taking care to judge a design conservatively and with a critical eye is a part of codes such as the IEEE statement to "be honest and realistic in stating claims or estimates based on available data." Similarly, the American Society of Civil Engineers (ASCE) calls for engineers to "be dignified and modest in explaining their work and merit."[24] Further, some codes encourage engineers to be forthright about the possibility for making mistakes, for example, IEEE exhorts them "to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors."

Speaking on the need for humility when considering the effects of technology, Congressman Sherwood Boehlert noted that "our record when it comes to technology is not very good. But how good can we expect to be? The social consequences of technology - the most subtle and far-reaching impacts - are the most difficult to predict and even more difficult to forestall."[25] However, speaking at the same hearing, Ray Kurzweil did not exhibit much technological humility: "We are immeasurably better off as a result of technology, but there is still a lot of suffering in the world to overcome. We have a moral imperative, therefore, to continue the pursuit of knowledge and advanced technologies, such as nanotechnology, that can continue to overcome human affliction."[26]

Pride goeth before a fall even in technology. Ghandi said "It is unwise to be too sure of one's own wisdom. It is healthy to be reminded that the strongest might weaken and the wisest might err." Overconfidence in a design leads one to make overly broad claims about its capabilities, or to expect more than is reasonable. Pride can blind the designer to flaws in their design, so that even when double-checking their work, they may unintentionally gloss over errors. Humble design acknowledges the likelihood of errors in the initial approach and thus encourages double-checking, multiple models to validate an answer, peer-review, and so forth. Humility also requires that we do not completely trust the review process, allowing for the possibility that errors or misconceptions might remain. Thus, humble design requires substantial feedback to the user of the technology. A warning light, or perhaps a mechanical stop, informs the user if they attempt to perform some action that pushes the technology out of its designed range of operation. A computer error message should indicate which actions led to the problem. The user's mental model of a technological product helps them understand how to use the technology.[27] Thus, error feedback to the user is an indicator that the user's mental model of the technology does not match the designer's model of the technology. Because we are humble enough to admit our products will wear out, the user's manual should include information on maintaining the product and replacing broken parts. Feedback is also important when the designer's mental model does not precisely match reality. In this case, if some parameter of the design, temperature perhaps, goes outside the expected bounds even while the design is in its intended range of operation, then this indicates the design model was not completely accurate and feedback can be useful as a warning of this situation.

Humility, both professional and personal, also leads us to recognize human limitations and frailty. The human mind is incredibly complex and wonderfully creative, but it is not boundless in ability. The virtue of humility calls us to recognize explicitly our human limitations. We cannot rely entirely on our own ability to produce completely safe and reliable systems. An example of such recognition of limited human capability can be found in computer systems that use not only redundant hardware but also use diverse software (so called multi-version or Nversion software). This approach to software uses three or more versions of software to do the same task, each developed by independent software engineers. The system votes on the outputs, with the hope that the software is mostly reliable, so that the few bugs remaining in the software will occur at different points. Thus, the voted results will be much more reliable than that of any of the individual programs.

7 Conclusion

The norm of justice keeps our eyes open for inequity caused by the choices we make regarding technology. The norm of humility gives us technological modesty so that we take extra care in designing technology. Designing and using technology is part of what makes us human. Education in the liberal arts helps us put technology in context to see its broader implications. Norms for design and use of technology can help engineers and all of us to make more appropriate, more humane choices regarding technological products.

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[1] Z. Dienes and G. Altmann, "Transfer of implicit knowledge across domains? How implicit and how abstract?" In D. Berry (Ed.), *How Implicit is Implicit Learning?* Oxford: Oxford University Press, 1997, pp 107-123.

[2] Steven H. VanderLeest, "The Built-in Bias of Technology," *Proceedings of the 2004 American Society for Engineering Education (ASEE) Conference*, Salt Lake City, Utah, June, 2004, pp. 1417-1427.

[3] Gayle E. Ermer and Steven H. VanderLeest, "Using Design Norms to Teach Engineering Ethics," *Proceedings of the 2002 American Society for Engineering Education (ASEE) Conference*, Montreal, Quebec, Canada, June, 2002, pp. 9025-9034.

[4] Langdon Winner, "Do Artifacts Have Politics?" *Daedalus* v. 109, n. 1, Winter 1980, p. 121-36.

[5] Plato, *Phaedrus*, translated by Benjamin Jowett, The Macmillan Company., 1892.

[6] Karl Marx, tr. Samuel Moore and Edward Aveling, ed. Frederick Engels, *Capital*, Marx/Engels Internet Archive, http://www.marxists.org/archive/marx/works/1867-c1/ch07.htm#4a, accessed 2 Jan 2006.

[7] Abraham Maslow, *Motivation and Personality*, 1954.

[8] Pope Paul VI, "Message for the Celebration of the Day of Peace," 1 Jan 1972.

[9] Stephen V. Monsma, ed. *Responsible Technology: A Christian Perspective*. Grand Rapids: Eerdmans, 1986.

[10] Egbert Schuurman, *Perspectives on Technology and Culture*, Sioux Center: Dordt College Press, 1995.

[11] Monsma (1986), p. 74.

[12] John Rawls, *A Theory of Justice* (Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 1971), p. 62.

[13] Rawls (1971), p. 157.

[14] Rawls (1971), p. 158.

[15] Steven H. VanderLeest "Justice and the Non-Neutrality of Technology," Spirituality, Justice, and Pedagogy Conference, Grand Rapids, MI, 22-24 September, 2005.

[16] Robert Nozick, *Anarchy, State, and Utopia* (New York: Basic Books, Inc., 1974), p. 151.

[17] Nozick (1974), p. ix.

[18] Nozick (1974), p. 163.

[19] Bob Goudzwaard, *Aid for the Overdeveloped West*, Toronto: Wedge Publishing Foundation, 1975.

[20] National Telecommunications and Information Administration "Falling through the Net: Toward Digital Inclusion" (2000), http://www.ntia.doc.gov/ntiahome/digitaldivide (19 Sep 2005).

[21] Robert J. Furey, *So I'm Not Perfect: A Psychology of Humility*, New York: Alba House, 1986, p. 18.

[22] IEEE Code of Ethics, http://www.ieee.org/portal/pages/about/whatis/code.html, accessed 5 Jan 2006.

[23] NSPE Code of Ethics for Engineers, http://www.nspe.org/ethics/eh1-code.asp, accessed 5 Jan 2006.

[24] ASCE Code of Ethics, http://www.asce.org/inside/codeofethics.cfm, accessed 5 Jan 2006.

[25] Sherwood Boehlert, "Opening Statement for Hearing on Nano Consequences," Committee on Science, U.S. House of Representatives, Hearing, April 9, 2003, http://www.house.gov/science/hearings/full03/apr09/boehlert.htm, accessed on 10 Jan 2006.

[26] Ray Kurzweil, "Testimony of Ray Kurzweil on the Societal Implications of Nanotechnology", Committee on Science, U.S. House of Representatives, Hearing, April 9, 2003, http://www.house.gov/science/hearings/full03/apr09/kurzweil.pdf, accessed on 10 Jan 2006.

[27] W. Bernard Carlson, "Toward a Philosophy of Engineering: The Role of Representation," *Proceedings of the 2003 American Society for Engineering Education (ASEE) Conference*, Nashville, Tennessee, June, 2003.