Widening Access and Narrowing Focus: Could the Internet Balkanize Science?

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Working with information requires time and attention. A wealth of information leads to a poverty of attention, creating a need to allocate attention efficiently. Not surprisingly, the online information explosion makes explicit searching and filtering not only possible but also necessary. Automated agents can scan the World Wide Web for focused information based on predetermined preferences while collaborative filters master new preferences by comparing hundreds of thousands of user profiles to make strikingly accurate suggestions on information of potential interest. Highly customized online journals, with a subscriber base of one, have become feasible.

Organizational structures are also changing. Plummeting costs of information technology (IT) have changed the relative efficiency of different structures for coordinating work in firms and markets (1) and in universities (2). Increased integration and collaboration – as well as competition – may follow. Although most research (and press attention) has focused on business restructuring, the structure of scientific inquiry is not immune to a changing technological environment. In particular, the unifying and integrating benefits of access technology should not be taken for granted. Recent work shows that greater access to specialized and remote resources can increase scientific productivity but that scientific insularity might also rise (3). Faced with a wealth of resources and limited attention, researchers can use IT to focus on only those articles and colleagues that really interest them, regardless of location, and to the effective exclusion of others.

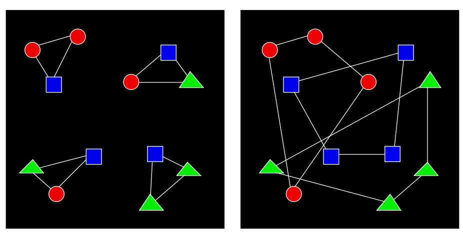

Figure 1.A **Figure 1.B**

IT can reconstitute geographic communities (locations in 1.A) by research discipline (colors in 1.B).

Benefits of Electronic Collaboration

The proof of Fermat's last theorem offers an illustration. Discovery of a glitch in the original version sparked an electronic exchange of ideas among internationally distributed algebraic topologists. Long distance dialogue then led the author, Andrew Wiles, to strengthen his ideas and fix the proof. Focused interactions enhanced productivity within this mathematical subspecialty – even as its members turned from other tasks in their efforts to be among the first to find new answers.

Scientists who use IT appear to be more productive – they reportedly write more papers, earn greater peer recognition, and know more colleagues (4). "Collaboratories" provide new ways to coordinate large-scale research projects and to access remote data sets, research specialists, and equipment (5). This evidence supports the promise of the World Wide Web to build broader, richer scientific communities. The particle physicists group at CERN, after all, designed the Web to enhance collaboration.

Electronic Balkanization

Yet, if IT helps an algebraic topologist in North America spend more time interacting with colleagues in Europe, Asia, and elsewhere, what happens to his or her interactions with the computer scientist, the biologist, or the graduate student who works down the hall? As quickly as IT collapses barriers based on geography, it forces us to build new ones based on interest or time. Ironically, global communication networks can leave intact or even promote partitions based on specialty, politics or perceived rank – divisions that can matter far more than geography.

Thomas Kuhn identified the widening gulf between scientific specialists as a problem over three decades ago (6). The power of emerging IT to search, connect, screen, and select can exacerbate this problem. An IT telescope that brings distant colleagues into focus can

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inadvertently produce tunnel vision and peripheral blindness. Geographic balkanization, which might have separated scientists in physical space, can give way to electronic balkanization, which separates them in "topic space".

Figure 1 shows how.

In figure 1, local connections are traded for long-distance connections with greater relevance by interest group. Because the Internet makes it easier to find colleagues with similar interests, professional integration substitutes for geographic integration. These interactions can also be modeled formally. Let the topics be indexed by $t \in \{1, 2, ...T\}$ and the community members who are aware of a given topic be M(t), then as one index of

$$\beta \equiv 1 - \frac{1}{T}\frac{1}{T-1} \sum_{t \in \{1,2...T\}}^{T} \sum_{s \neq t}^{T} \frac{|M(t) \cap M(s)|^2}{|M(t)||M(s)|}$$

"balkanization" we can define:

In the figure, balkanization rises from .35 to 1 as inter-group interaction declines. More generally, models and numerical simulations reveal that this and other metrics of balkanization can increase as technology improves searching, filtering and long-distance collaboration.

Preferences and Private versus Social Incentives

As access technology improves, individual preferences largely determine whether balkanization increases or decreases. If scientists prefer more focused interaction than is available locally, then to the extent IT helps scientists to satisfy these preferences, an increase in IT will lead to more narrow scientific interactions. Because the Internet makes it easier to find more interesting contacts, those less interesting contacts near the threshold of attention may be abandoned. Unless scientists actively seek diversity, global access might therefore balkanize interactions.

Thus marine hydrodynamics and computational fluid dynamics have emerged among thousands of new and distinct discussion groups across the Internet. The narrower the focus, the greater the depth of interaction on a given research topic. Focus is a response to the poverty of attention. When daily interactions bombard us with irrelevant information, a strong desire to focus might evolve as a useful heuristic for minimizing distractions. By radically improving filtering, however, advanced IT can lead this same heuristic to inordinately favor depth at too great a cost in breadth. Old strategies can become counterproductive in new environments.

Developing many new contacts within a specialty also calls for a second form of focus: an emphasis on quality. The World Wide Web accumulates two hundred thousand new pages daily, along with thousands of postings to public discussion groups – a wealth of information that creates a need to sort the diamonds from the dust. To preserve the caliber of interaction, most prominent scientists retreat to small private e-mail lists and invited discussion groups (7, 8). This screening process grows increasingly efficient. The recently announced Platform for Internet Content Selection will not only enable the labeling of material in online journals (e.g. "seminal article"), but the creators foresee "labels for Usenet authors according to the quality of the messages they post: posts from those with poor reputations could be screened out" (9 p. 93). Communications that once depended on geography, proximity, and serendipity are screened and filtered for perceived relevance and reputation. Separation and stratification can easily result.

Science advances not just from publication, but from dialogue, apprenticeship, and collaboration. Although we commonly think of scientific knowledge as a public good – available at zero cost once it has been produced – the specialized skills, education, and foreknowledge needed to use it imply that scientific information is far from free. Incentives are necessary to encourage creation, distribution and use.

The incentives faced by individual scientists, however, do not automatically lead them to act in ways that maximize scientific progress. Overspecialization, for example, can be privately beneficial while having the effect of erecting virtual walls between scholarly communities. If intra-disciplinary interactions substitute for inter-disciplinary interactions, then the intellectual cross-pollination of ideas can suffer. Consider that the Black-Scholes equation for pricing financial options is derived from an arbitrage model that leads to the heat transfer equation (10). Conceivably, reducing the spillovers between thermodynamics and finance could have forestalled the development of options markets. Similarly, the Alvarez theory that an extraterrestrial impact led to the extinction of the dinosaurs originated from the collaboration of a geologist and a physicist at UC, Berkeley. Crick's training in physics and Watson's background in zoology helped them develop their theories of DNA (11). In general, the insularity of sub-populations negatively affects the speed at which new ideas percolate through an entire population (12).

Conclusions

The balkanization of science is by no means inevitable. A scientist may use IT to select diverse contacts as easily as specialized contacts. Whether technology contributes to integration or fragmentation hinges on individual preferences and factors such as whether the pressure to publish at the frontier of one's own discipline is low enough to permit time for exploration in others.

New technologies give us options that we never had to consider before. They enable both the global village and the virtual Balkans of scientific collaboration. While no single scenario is inevitable, certain outcomes, once achieved, can be difficult to reverse. At this early stage of developing information infrastructure, we can, and should, explicitly consider what we value as we shape the nature of our networks – with no illusions that a greater sense of community will inexorably result.

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