Fall 2000

explore, Fall 2000: The School of Engineering

Ignatian Center for Jesuit Education

IN THIS ISSUE

LETTER FROM THE INSTITUTE DIRECTOR

As we focus on the Santa Clara School of Engineering in this issue, we complete our examination of how the commitment to justice influences the teaching and education in the major schools at Santa Clara University. Silicon Valley is the technological capital of the globe, the place where we find the nation's highest levels of education and income per capita. How do we teach students to keep sight of ethical issues in this intensely competitive culture?

The well-publicized, "digital divide" is just one of the many urgent ethical questions in engineering. Dean Terry Shoup writes about several undergraduates who have used their senior capstone projects to work on "appropriate technologies" to benefit the disabled and others who often get bypassed by conventional technology producers. Steven Chiesa, the assistant dean, describes how justice should play a major part in civil engineering projects. "Environmental justice" looks at the impact of refineries and waste treatment plants, for example, on the quality of life of the people who live near them.

Santa Clara is proud of the racial and ethnic diversity in its engineering program, but why do relatively few well-qualified women choose to enter the field? Professor Ruth Davis from computer engineering describes a series of major grants she has received to encourage young women to pursue careers in science, technology, and engineering. She has worked with women students to develop product prototypes in areas that males have overlooked, such as a universally accessible family calendar and fetal monitoring systems.

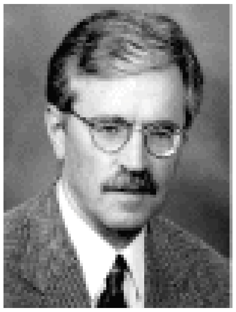
Peggy Shen '00, the first student awarded the dean's graduate honors fellowship, relates her work in developing a new course requirement for all graduate students that raises the human dimensions of their professional work.

Dennis Smolarski, Sj. of the mathematics and computer science department offers a rich account of the roots of Jesuit interest in technology in his essay on the *Ratio Studiorum*, the legendary 400-year-old program for Jesuit schools. How did this tradition that emphasized the liberal arts and humanistic studies make room for the New Science? How is Jesuit education responding to todays technological revolution?

And lastly the Barman Institute bids farewell to two great women. We thank Bernadette Proulx for her years of service to both the Bannan Institute and to Santa Clara University. Bernadette helped to develop this very publication and organized many programs with creativity and efficiency. And we congratulate Denise Carmody as she assumes her duties as Acting Provost of the University. The steering committee has benefited from her wisdom and good humor for the past four years, and we are grateful for her leadership of the Santa Clara Lectures.

The publication of this issue of **explore** coincides with both the beginning of Santa Clards 150th anniversary celebration and with the national conference, *The Commitment to justice in Jesuit Higher Education.* On behalf of The Barman Institute, I offer special thanks to the Arline and Thomas J. Barman Foundation for its very generous support.

Cordially,



William C. Spohn
Director

The senior capstone experience has long been a showcase activity for the School of Engineering at Santa Clara University. Without exception, the projects undertaken have provided our students with a superb experience in the competence aspect of engineering. In this experience, which normally lasts the entire senior year, students begin with a project of their choice and pursue a real engineering process from design through construction and testing.

Frequently Santa Clara engineering students win awards for their remarkable designs. Many even find that this experience enhances their career possibilities. The School of Engineering recently began to provide incentives to encourage projects that foster conscience and compassion as well as competence. As a result, we have established special senior project grants for up to $3000. (Students apply by submitting a short proposal.) Projects that are eligible for funding under this unique program must satisfy one or more of the following criteria:

- They must provide a meaningful experience that integrates knowledge into a single design experience.
- They must involve cross-disciplinary teams of students.
- They must involve partnerships with external organizations most familiar with the need.
- They must involve the design of projects, systems, and processes that benefit people, with particular emphasis on the under-served in society.

The current program has grown out of nearly 10 years of informal encouragement of similar “appropriate technology” projects. In the past, students have worked on senior designs that might improve the lives of people in third world countries (water supply and wastewater treatment projects, a methane-powered electrical generator, and the design of housing to meet the needs of low income families), meet needs of disabled persons (a hand-powered tricycle for wheelchair riders and a device to evaluate handicapped accessibility of trails), and address social needs in the United States (design of playground equipment for inner-city children). Current projects include designing an improved hockey sled for the U.S. paralympic hockey team and developing a wrist exerciser that may reduce repetitive strain injuries for people in wheelchairs.

Inspiration and ideas for justice-related projects come from many sources. Some ideas come directly from the students, while faculty advisors suggest other ideas. Friends and alumni of Santa Clara are another fruitful source of project ideas. For example, the late Don Ruder, a member of the Engineering School Advisory Board, proposed several of the projects related to third world infrastructure issues. Peter Axelson, founder of Beneficial Designs Incorporated and himself a paraplegic, has suggested and helped to fund several of the more recent projects related to disabled individuals.

One such project was a device to evaluate trails for handicapped accessibility, with a design goal of cutting the time it took to survey a trail by a factor of 10. The team of Ben Blaine, Scott Hempey, Christopher Hintz, and Karie Rewak designed their Camptrail Cart during 1997–98. Ben, now a graduate student in Mechanical Engineering at Santa Clara, noted that his interest in working on a project that helped people was piqued by a summer internship at a medical equipment company. And he and his teammates got a great deal of satisfaction from their efforts. “That’s why our project was so neat,” Ben said. “You’re working with people who are just trying to improve human beings’ lives.”

A student’s initial motivation for choosing a justice-related project is not always as noble as Ben’s. Joe McGarry, who is currently designing an improved hockey sled for the United States paralympic hockey team with teammate Greg McPheeters, simply wanted to enable others to enjoy competitive sports as he does. But the experience of interviewing several players on the United States team, and skating with the team captain in Southern California, has changed his view of engineering. “The interaction with the players has been really great, and I’m much more aware now of the actual social impact I have as an engineer,” said Joe. This project is about more than sports: Greg noted that one of their principle design goals, along with better maneuverability and body control, is improved safety over current sleds, whose riders frequently suffer broken ankles from collisions with other players. A secondary goal is to consider ways to make the sleds adjustable so they can fit different people, making it less expensive to equip a team and putting the sport within reach of many more individuals.

These justice-oriented projects affect more than the students who work on the designs. Vice Provost Philip “Boo” Riley’s daughter, Eliza, has cerebral palsy. Several years ago a team undertook a project to design a recumbent bicycle for her, hoping to build pedaling mechanisms that would allow her to take maximum advantage of the limited range of leg movement the disease allows. Although the project was unable to produce a bicycle that worked, they met with Eliza and her therapist regularly. “I thought it was great that she had a chance to interact so closely with a group of college students,” Boo said.

In a typical year, approximately ten percent of the senior design projects are justice-related. As the above comments indicate, the impact on the students doing these types of projects is tremendous. And the efforts of these students helps their classmates see the tremendous potential for engineering designs that help others.

Terry E. Shoup
Dean and Sobrato Professor,
School of Engineering
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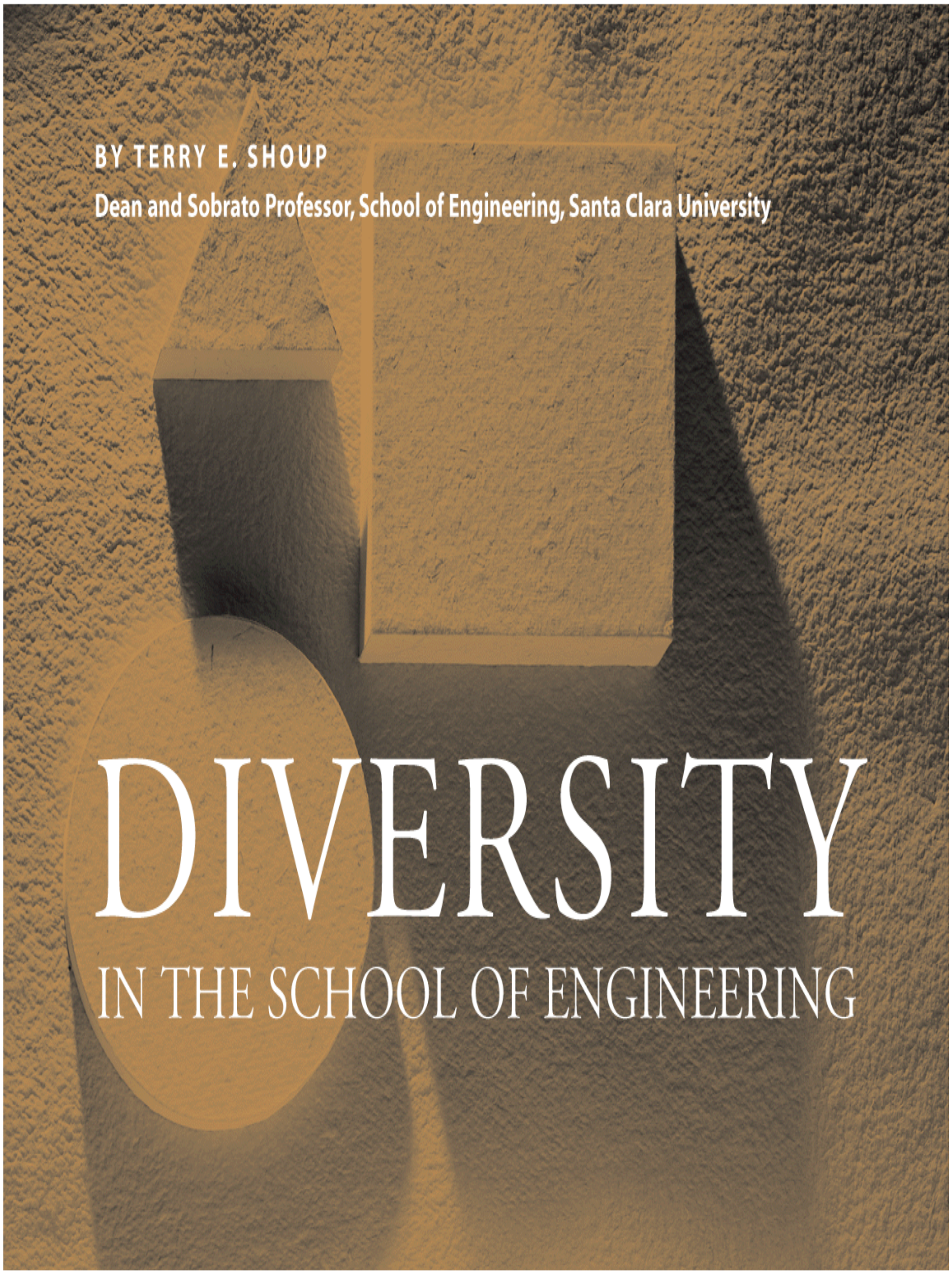

The School of Engineering is more racially and ethnically diverse than the University as a whole, with 46% minority students at the undergraduate level and 64% minority students at the graduate level. Female students make up a much smaller proportion of students at both levels than in the University at large (figures that reflect national trends). Our minority population reflects the diversity of the local community as well as the efforts of our high school outreach programs, including the Summer Engineering Seminar (SES), which provides two weeklong introductions to engineering sessions each summer; and the Academic Enrichment Seminars (ACES), a series of Saturday workshops/seminars in engineering. The Science and Technology Activity Resource Seminars (STARS) program targets fifth and sixth graders. The engineering school, in collaboration with the Minority Engineering Program Industry Advisory Board (MEP/IAB), also sponsors Educator Breakfasts, bringing together high school and community leaders in targeted areas to educate them about the many programs that the SCU School of Engineering has to offer.

The diversity of the student population is a wonderful resource. At the same time, it can be a challenge to meet the needs of the many diverse groups on campus. The MEP/IAB sponsors several programs and student groups that provide support and encouragement to minority students. Formal support programs that target underrepresented students at SCU include Frontiers for Underrepresented Students in Engineering (FUSE), a pre-orientation program for SCU freshmen; and Mentoring Underrepresented Students in Engineering (MUSE), a mentoring program for SCU undergraduates.

Often, however, the most valuable support is that provided by other under- represented students through student clubs, such as the National Society of Black Engineers (NSBE), the Chicanos and Latinos in Engineering and Science at SCU (ChALESS), which is also affiliated with the Society of Hispanic Professional Engineers (SHPE), and the Society of Women Engineers (SWE).

Margo Gaitan, J. Fernando Arguello, and Cindy Interiano were President, Vice President, and Finance Officer, respectively, of ChaLESS during the 1999–2000 academic year. All three were involved with FUSE and MUSE during their freshman year, and speak passionately about the importance of fellow Hispanic students to their success at Santa Clara. “ChaLESS was one of those comfort zones I needed when I first came here,” Cindy says. “The members convinced me I was there for a purpose and motivated me to stay.” Margo is even more direct about how much fellow students helped her: “Engineering is a tough major, and for people who have had no contact with it beforehand, it’s a new world. I would have dropped out freshman year, at least from engineering, without that support.”

The local student clubs organize activities during the academic year, ranging from purely social events to workshops on academic success skills and presentations by alumni who are now working in the field. Being affiliated with national organizations offers further possibilities to students to gain skills and motivations. Fernando attended the SHPE national conference during winter quarter 2000. “The conferences are really good,” he says. “They provide wonderful opportunities for networking, and the workshops have taught me things that I know work in the classroom.”

ChaLESS members also have a strong sense of obligation to other students following in their footsteps. That means recruiting new freshmen to the organization, but it also involves community outreach activities such as tutoring high school students and speaking to students at high schools and middle schools. “We talk to them about staying on track with their education so they can continue with after high school, regardless of whether it’s at a community college or a four-year school like Santa Clara,” says Margo. “It’s one of the most satisfying things we do. Everyone who participates comes back with a real sense of fulfillment.”

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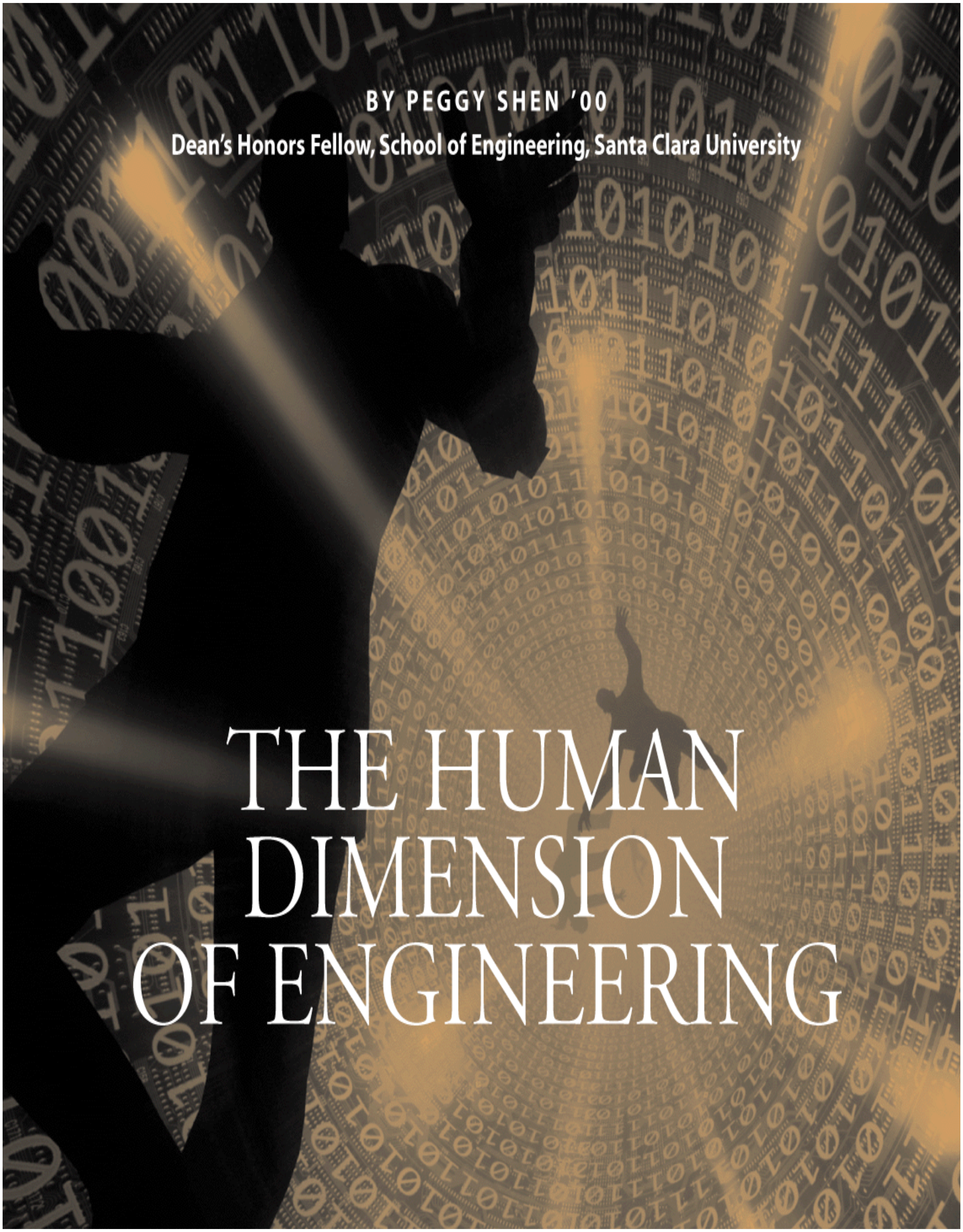

When AWZ.com offered a chance to win an iMac for registering with the online site, did they realize that the winner would not be able to connect to their site using the prize computer? Myra Jodie, the winner of the computer, lives on a Navajo Reservation with no running water and no telephone line. So far, her only access to the Internet and computers has been through her school in Arizona. Do we engineers, most of whom have access to more than one computer at home and work, realize that technology does not penetrate every part of society and every part of the world? How does this "Digital Divide" impact our engineering community? And what can we do to allay this gap between the "haves" and the "have-nots"?

When the decision to launch the space shuttle Challenger on January 28, 1986, was made, the political and economic pressures overrode the concerns of the rocket design engineers. This decision led to what many consider to be the worst space disaster in history. The events leading up to this are well documented and this story is a common model for ethical decision-making. Was there more the individual engineer could have done to prevent this tragedy? This leads to more general questions about whistle-blowing. What are our responsibilities as engineers in these types of situations? What are the consequences of whistle-blowing? How do we as engineers pursue ethical decision-making? How do we influence the outcomes of critical situations?

These issues are not addressed in most engineering graduate schools, even though they are an integral part of engineering. Engineering has long been a field in which problem solving is taught as a methodical, scientific, and practical process. Often, the human dimension is overlooked in engineering classes since it is not inherent in standard engineering solutions and approaches.

With technology advancing at an amazingly rapid rate, we seem to have little understanding of its present and future impacts. We also have little understanding of how to approach moral dilemmas that arise from this advance of technology. There are few historical models to guide us in this area, so we need to develop new models and laws. Determining these models and laws is a difficult task due to the varying interests of individuals, special interest groups, our government, and the government and peoples of other nations. Even though issues related to the impacts of technology are much more difficult to grasp and resolve than the practical and mathematical aspects of engineering, understanding the effect of engineering on our businesses, our communities, and our personal lives is a crucial requirement for today's engineer.

ISSUES IN PROFESSIONAL PRACTICE COURSE REQUIREMENT

To address this need, the School of Engineering at Santa Clara University will require every graduate engineer to take a course related to issues in professional practice beginning in fall 2000. The purpose of this requirement is to help graduate students develop a better understanding of the human dimension of their professional work. This requirement is especially meaningful given the broad humanistic focus of the programs at a Jesuit Catholic university such as SCU. Courses that satisfy this requirement will provide enrichment to a student's program in a dimension that is both relevant to the practice of engineering and consistent with the elements of conscience and compassion. Although courses that meet this two-unit requirement will complement a student's preferred technical specialty, they will be different in content from the technical courses in the student's program.

Courses that satisfy this requirement will engage one or more of the following topical areas:

• developing sensitivity to other cultures in the local or global workplace
• understanding the social impacts and implications of engineering practice
• understanding the legal issues that impact society and engineering practice
• understanding the ethical dimensions of engineering practice
• understanding the environmental implications of engineering practice
• understanding and developing responsibility for professional service

One of the courses that will satisfy this requirement is entitled “Societal Issues in Engineering Professional Practice.” This course (to be offered for the first time in the spring 2001) addresses technology issues that are pertinent to Silicon Valley. The topics presented in this class each year will be selected and researched by the Dean’s Graduate Honors Fellows with the aid of the faculty throughout the University. The Dean’s Graduate Honors Fellowships are awarded to full time graduate students selected from the best applicants to the Graduate Engineering School. These engineers will be chosen based on their technical, communication, and leadership skills since they will play an active role in developing, implementing, and facilitating this new course under the direction of a faculty adviser.

I was involved in a pilot lecture/discussion class that was implemented to assess the effectiveness of this new course requirement for engineering students. This session focused on the issues of the “Digital Divide.” One mechanical engineering student who participated noted that the experience had made him much more attuned to the issue of the “Digital Divide” and how it appears in our everyday lives. He particularly noted that without the class, he probably would not have paid attention to Myra Jodie’s plight.

As the first graduate student awarded the Dean’s Graduate Honors Fellowship, I worked closely with the Dean and Associate Dean in researching and outlining recommendations for this course. This process gave me the opportunity to talk with faculty throughout the University and learn more about current engineering issues. This experience has profoundly affected my outlook on contemporary issues related to my career and personal life. I was able to understand the unique perspective that Santa Clara University provides its graduate students, who come to the University to acquire competence in technical fields and leave with a richer dimension including conscience and compassion.

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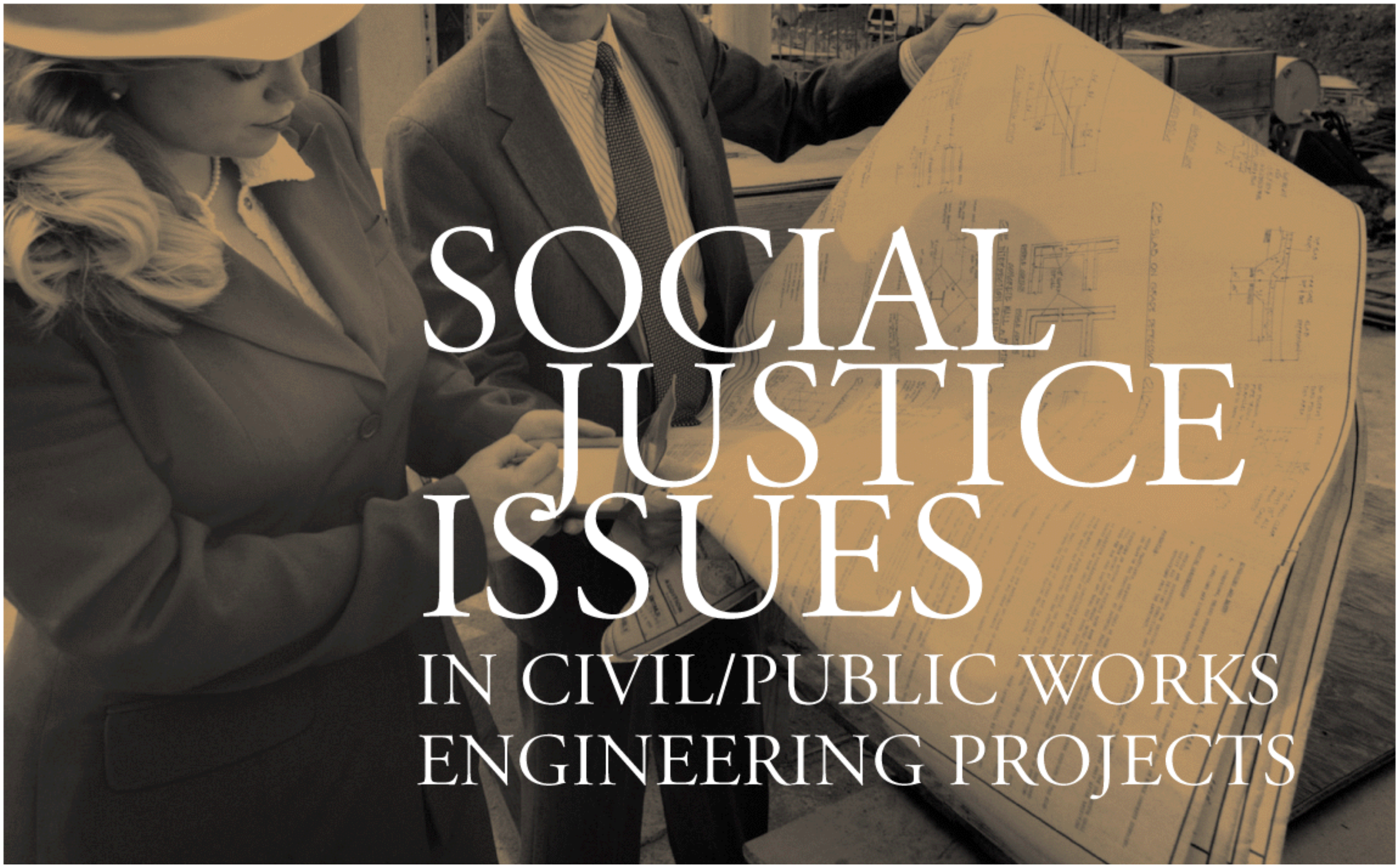

Though at first it might seem that civil engineered projects are cut-and-dry technical matters, there are many social issues to be addressed in most large-scale, government funded public works projects. A list of typical projects would include those related to housing, transportation, water supply, waste disposal, and flood management. Individual projects could take the form of buildings and other large public structures; bridges, highways, and mass transit systems; water treatment plants and pipeline delivery networks; wastewater collection, treatment, and disposal facilities; sanitary landfills; and dams, reservoirs, and drainage channels. These projects have a direct bearing on quality of life issues within any community and its local environment.

The absolute size of such projects frequently places significant demands on the financial and environmental resources of the communities the projects are intended to serve. There is also a danger that benefits, as well as costs, may not be shared equitably among affected parties. Accordingly, the impacts that such critical quality-of-life projects have on all affected community members should be clearly addressed before any plan of action is implemented.

The typical chronological development of many public works projects can be seen in Figure 1. In this project chronology, social justice issues must be included at the earliest stages of development. Once a project reaches the design phase (or beyond), it becomes increasingly more difficult and expensive to modify the plan. It is most logical and practical to address potential social justice issues during the determination of need and project planning stages. During these two stages, there should be ample time to assess the needs and projected impacts on all constituencies and ensure a fair distribution of short-term and long-term project benefits and costs.

All communities must confront the needs of their citizens by examining what issues most directly influence actual or perceived local/regional quality of life. The allocation of limited funds then must somehow be prioritized to best meet key community needs. To ensure that resources are fairly allocated, community needs must be determined in an objective way. However, this needs-assessment process can be unintentionally subverted. Well-organized, energetic advocacy campaigns by small constituent groups on behalf of a particular project may distort the project's true need relative to other projects. Equally justifiable projects, benefiting elements of the community that lack such advocacy prowess, may unintentionally be given lower funding priority because the projects' needs were not as effectively expounded or lobbied.

Once a list of potential projects has been developed based on a needs assessment, projects are often evaluated in terms of the ratio of projected benefits to projected costs. This benefit-to-cost ratio approach historically has been used to justify the expenditure of tax dollars. Any project with a calculated benefit-to-cost ratio greater than one conceptually would be worthy of funding. Even for those projects with acceptable benefit-to-cost ratios, however, there is no assurance that benefits and costs will be realized equitably throughout the impacted community. Indeed, some smaller scale projects, by their very nature and intent, tend to benefit one local constituent group over another. A reasonable method of long-term oversight would be advantageous in making sure that the cumulative costs and benefits over time for funded/implemented projects are equitably distributed. In certain cases, funding of a limited number of targeted projects with marginal benefit-to-cost ratios may be a practical way to help equalize long-term benefits among all constituencies and minimize the potential for resentment between different groups.

The detailed planning step for public works projects offers the greatest arena for inclusion of social justice issues. It is during this phase that major decisions are made regarding the technical, financial, and environmental viability of individual project alternatives. These decisions will have a direct bearing on the location/routing of major project components, the need for and use of mitigation measures to reduce environmental impacts, and the financial cost burden directly or indirectly placed on the local community.

Many publicly funded projects require, by law, the preparation of formal documents identifying the environmental consequences of proposed project alternatives. While these activities have historically focused on the effects a project alternative would have on local natural resources, an increasing emphasis is now being placed on related socioeconomic impacts. Some projects, for example, may necessitate obtaining access easements and/or purchasing outright privately held property. As project cost containment is always an important consideration, viable but highly valued sites are usually quickly eliminated from consideration, skewing the selection process toward low-cost and low-income areas. While fair market value is typically used as the criterion for compensating property owners via negotiation or eminent domain, displacement of small businesses and/or low-income families may still create socially unjust financial hardships if local, equivalent relocation options are limited or nonexistent.

A major redevelopment project currently being planned for a section of downtown Pittsburgh, Pa., is a prime example of how different constituencies are often at odds about the intent and impact of proposed projects. One highly empowered local group has promoted revitalizing the area by essentially leveling several downtown blocks to make room for a new, upscale shopping venue. Current shop owners and historic preservationists are leading the opposition to this redevelopment strategy. The shop owners are worried that the city's power of eminent domain and the upscale nature of the proposed area will be used to permanently displace their businesses. Preservationists believe an important part of the city's architectural history will be lost in such a process. Both sides believe that they are acting in the best long-term interests of the community, and it appears that any final decision will need to justify the related socioeconomic impacts and provide appropriate mitigating measures.

The location of waste management facilities similarly has seemed to have adversely affected lower income communities. Because of a variety of reasons including lower land costs, less public resistance, and more transient populations, waste management facilities are much more frequently found in or near low-income neighborhoods. The presence of such facilities then contributes to lower local property values and lower property tax-related resources for the area. The historical tendency to locate waste management facilities in low-income/minority populated areas was specifically addressed when President Clinton issued Executive Order 12898 on February 11, 1994. This effort directed all federal agencies to make environmental justice an integral part of their policies and activities. The (federal) Environmental Protection Agency created an Office of Environmental Justice, which has worked to develop a supporting bureaucratic structure to ensure that the Agency would receive input from potentially impacted stakeholders. Details for this program, as well as related environmental justice concepts, are available on the web sites provided in Table 1. The need to address such socioeconomic issues in a project planning assessment phase will ensure that certain segments of the community do not bear the brunt of the entire community's more unappealing infrastructure.

Where does the discussion of such fairness issues fall in an undergraduate civil engineering curriculum? At Santa Clara University, these issues are addressed as part of a two-course capstone design project sequence. The first of the two courses, Civil Engineering Design Methods, deals with project development/chronology and the alternative evaluation and selection process. Here, fairness and justice are identified as possible evaluation criteria together with the more traditional concepts of technical, economic, and environmental feasibility.

In summary, there are several obvious places where social justice issues can and should come into play during the development of public works projects. While engineers and public planners may be aware of and even trained to deal with these very issues, panels of elected officials make the final project decisions. Each participant in the process, including the planners and engineers, has an ethical responsibility to see that the interests of all impacted parties are fairly and objectively represented. The size and nature of these projects will result in both benefits and disbenefits; an understanding of the individual and cumulative social consequences of these projects is an important aspect in maintaining a sense of fairness in community development.

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Some Significant Facts:

• In 1996, women accounted for only eight percent of engineers and twenty percent of all physical scientists in the workforce [National Science Foundation].
• Women earned 55 percent of all bachelor's degrees awarded in the United States in 1995, but only 17 percent of the bachelor's degrees awarded in engineering. This represents an improvement since the mid-'80s, except in computing, where the number of bachelor's degrees awarded to women has decreased by nearly a third since 1984 [Andrews, Camp, U. S. Department of Education].
• Blacks, Hispanics, American Indians, and Alaskan Natives represent over 23 percent of the U.S. population, but only 13 percent of bachelor's degrees in Science and Engineering (which includes social and natural sciences) [National Science Foundation].
• Half of qualified males choose a scientific career compared to only 16 percent of qualified females. However, once that choice is made, women are actually more likely to complete their degrees [Klawe and Leveson].

There is something wrong here, from many different perspectives.

Consider the shortage of information technology (IT) workers that seems to be in the news weekly. According to Meta Group, 400,000 IT positions are vacant in the United States today. Joint Venture: Silicon Valley reports that in Silicon Valley alone, there are 160,000 unfilled IT jobs, which cost high-tech companies between $3 billion and $4 billion in lost production each year. It is interesting to note that, if women had been attracted to computing disciplines at the same rate as men since the mid-'80s, there would be no shortage of workers today [Freeman and Aspray].

The average IT worker earns 78 percent more than the average non-IT worker, according to the National Telecommunications and Information Administration. The monopolization of high paying jobs by a relatively privileged class, white males, is an obvious social justice issue.

However, there is a more subtle justice issue involved here: society at large loses when only a small, reasonably homogeneous world view is considered in the design of new products and technologies. One might argue whether white men, minorities, and women think differently; one cannot dispute the fact that their life experiences are different. And one cannot help but be influenced by one's own experience in brainstorming about useful products for the future. A greater variety of products, useful to a wider population, is likely to result when one includes a greater diversity of experiences and perspectives in the design.

My own efforts to enhance the diversity of the engineering workforce started with my involvement with our student chapter of the Society of Women Engineers (as faculty adviser) and with the Summer Engineering Seminars program, where I have taught the computer applications sessions each summer for the past ten years. Very recently, I began to wonder about the effect these programs, and others like them, have on the retention of minority students and particularly women in engineering-related fields.

Last summer I ran a workshop sponsored by the National Science Foundation for people who develop and run programs to encourage girls to pursue study in Science, Technology, Engineering, and Mathematics (STEM). Forty-four program directors, developers, and teachers came to SCU in August 1999 to share their experiences and to investigate ways to motivate their students to persist in STEM fields. With the help of Drs. Eleanor Willemsen and Kieran Sullivan of the psychology department, we learned a lot about assessment and the developmental attributes contributing to motivation and persistence, and developed some preliminary surveys designed to help track students' long-term persistence. The website for the conference and follow-up survey project (http://www.scu.edu/SCU/Projects/NSFWorkshop99/) contains summaries of some of the presentations, position papers contributed by the participants, and the draft surveys.

In addition to motivating pre-college students to enter and persist in engineering studies, we need to support women who are already engineering students, in part by providing meaningful opportunities to use their engineering skills. One group that has been very active in supporting women in technology fields is the Institute for Women and Technology (IWT), founded by Anita Borg. The goals of the IWT are: to increase the impact of women on technology, in education, design, development, deployment, and policy; to increase the positive impact of technology on the lives of all women; and to help communities, industry, education, and governments accelerate and benefit from these increases.

In cooperation with the IWT, the SCU School of Engineering ran a workshop in January 1999 aimed at soliciting ideas about technology applications for the family from women of all ages and backgrounds. Following that workshop and several similar sessions held around the country, IWT decided to further develop the ideas generated by setting up a Virtual Development Center (VDC) to create product prototypes. A VDC is a geographically distributed set of development sites that work independently but share ideas, experience, and successes periodically.

In August 1999, along with sister sites at M.I.T., Texas A&M, and Purdue University, SCU became one of the pioneer VDC sites. Our leadership team includes myself, Barbara Molony, professor of history and director of the Program for the Study of Women and Gender, and Lee Hornberger, associate dean of engineering. Like the other VDC site schools, we received assistance in running another product idea workshop in October 1999, and were granted nearly $500,000 in equipment from Hewlett-Packard. Based on the workshops, we started a pair of development projects through the engineering senior design capstone course. We've also begun developing guidelines to allow us to implement biomedical design projects in the future and to investigate the way women students in engineering use handheld computers. The VDC website (http://www.cse.scu.edu/~rdavis/vdc) contains additional information beyond the brief summaries below.

The handheld computer project helps tie together the NSF workshop with the VDC goals. I have distributed 55 computers to freshman and sophomore women in engineering. I am interested in whether young women use handheld computers in the same way their male (early adopter) counterparts are expected to. How do they spend their time on these devices? What do they wish they could do? Most importantly, does the use of such a device improve their efficiency and retention?

Three computer engineering students are prototyping an idea that surfaced in one of our workshops as well as in several other workshops IWT has run: a universally accessible family calendar that allows separate views for commitments to work, family, and friends. Senior students Shianglin Mimi Chen, Sameer Shah, and Anu Maurya are using hardware and software support from the VDC in their implementation activities.

Another popular product idea was a self-cleaning house. There are many aspects to this vision, but one that is being addressed by Santa Clara students is a semi-autonomous vacuum cleaner. Gretchen Hellman and Saribel Daza, senior Electrical Engineering students, plan to build a vacuum cleaner that can be operated via remote control. While this is not likely to ease the worries of the busy women who want the vacuuming done for them while they are gone, it would be an incredible aid to people with disabilities who find it difficult, or impossible, to physically maneuver a vacuum cleaner.

Several of the product ideas involved medical technologies, an area in which Santa Clara students have little design experience. To establish the protocols and tools needed for students to begin to attack projects in this area, mechanical engineering students Ben Blaine, Elizabeth Drew, and Holli Ogle are developing a framework for performing biomedical product design. They are researching industry standards, regulatory agency issues, and the practices used by the designers at Hewlett-Packard in their development of the Viridia fetal monitor. Interviews with customers, equipment operators, and patients will document the utility, competitiveness, ease of use, and benefits of the resulting product. The final product of this project is an initial version of Santa Clara's biomedical product design handbook, with sections on materials, test methods, approval agencies, competitors, industrial design, and human factors engineering.

It's too early to say whether any of the prototypes will receive wide use or be refined into actual products. However, the students working on these projects report they are getting a great deal of satisfaction from designing prototypes that help women and families by solving real-world problems, and we expect the number of projects implemented through the VDC to grow over time.

In this essay, I have focused primarily on my work in supporting women students in engineering. Santa Clara's engineering school has many other programs to encourage minority and women students, including outreach programs to elementary, middle, and high school students, as well as mentoring programs and clubs for such students who are already enrolled. A complete description of the various programs and their activities would more than fill this issue of explore. They all stem from something we truly believe: if we can successfully attract and retain women and minorities in computing and other engineering disciplines, everyone wins.

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The Ratio Studiorum and New Technology: Opportunities and Challenges

Editor's Note: The following essay contains excerpts of an extensive paper presented by Dennis Smolarski, S.J., on November 22, 1999, at a conference entitled "Ratio Studiorum 400: Past, Present, and Future," organized by the Center for Culture and Dialogue, Jesuit College of Kraków, in Kraków, Poland.

Author's Note: A little over four hundred years ago, the definitive version of the Ratio Studiorum was approved by the Jesuit headquarters in Rome. This document was a "plan of studies" and guided the educational tradition of Jesuit schools for many, many years. In 1999, at "Ratio Studiorum 400: Past, Present, and Future" (one of the several conferences celebrating the anniversary of this document), I was invited to speak about how the principles found in this 400-year-old treatise would apply to technology and Jesuit education in the future.

I am grateful to the Bannan Institute for providing travel funds enabling me to participate in the conference and I am happy to share with you the fruit of my research and some of my suggestions for the future.

CONTEXT OF THE RATIO *WITHIN* THE SOCIETY OF JESUS

Since I will focus on the Ratio Studiorum and technology, let me begin by situating the Ratio in the context of the young Jesuit Order, and also by situating "technology" in the context of the disciplines mentioned in the Ratio.

Ignatius of Loyola gave the Society of Jesus and the world two major documents: The Spiritual Exercises and The Constitutions of the Society of Jesus. The Exercises focuses on an individual and on his or her personal relationship with God and others. In contrast, the Constitutions focus on a group–the Society of Jesus–and on its members, but also includes thoughts on a key Jesuit work: education, normally a group experience.

After Ignatius's death in 1556, it was felt that both of these documents needed commentaries to explain his thoughts and to offer additional guidance. As a result, 400 years ago, two other documents appeared. On January 8, 1599, the definitive version of the Ratio Studiorum was approved, expanding on Part IV of the Constitutions, and, on October 1, 1599, the definitive version of the Directory on the Spiritual Exercises.

Part IV of the Constitutions actually refers to a more detailed, "separate treatise" regarding schools, and the Ratio was that document. Even though neither the Constitutions nor the Ratio could mention any technology available to us today, in particular my field of computer science, nevertheless both refer to the foundational disciplines needed for any technology, namely, physics and mathematics. We should also note that the "mathematical sciences" in the sixteenth century included applied topics now considered separately as part of astronomy, physics, and engineering.1 Thus, I suggest, both the Constitutions and the Ratio can continue to give guidance as we stand on the brink of a new millennium and reflect on Jesuit education and on new academic and technical disciplines.

CONTEXT OF THE *RATIO* AND THE WORLD OF KNOWLEDGE

It is important to situate the Ratio among the significant events in the history of science. About 55 years before the 1599 Ratio appeared, Nicholas Copernicus published De revolutionibus orbium cœlestium;2 about 17 years before the Ratio,3 Pope Gregory XIII ordered the shift to the Gregorian Calendar based on the astronomical and mathematical work done by Jesuit Father Christopher Clavius; about 35 years after the Ratio, Galileo was condemned;4 and about 90 years after, Sir Isaac Newton published his Philosophiæ Naturalis Principia Mathematica.5 Thus the Ratio appeared about the same time as the beginnings of the scientific revolution, and so it is not surprising that the references to modern science it contains may seem sparse.

Another major factor to consider is the lack of prestige given in the sixteenth century to mathematics and to what we now call scientific and technical disciplines. At that time, a number of Italian philosophers, including some Jesuits, denied to pure mathematics the status of scientia, true scientific knowledge in Aristotle's sense, because it did not demonstrate its conclusions through causes and it dealt with abstractions in the intellect, rather than real objects.6 Thus, mathematics was not considered, by many, to be worthy of study in a university. Mathematics was presented via the subjects of the quadrivium, namely arithmetic, geometry, music (taught as applied arithmetic), and astronomy (taught as applied geometry), and also, in some degree, via logic (one subject of the trivium). But, at that time, the trivium and quadrivium were considered preparatory arts studied before one pursued the higher disciplines of theology, medicine, or law, which were usually the only accepted disciplines for university study, particularly in Italy.7

Evidence of the hostility toward mathematics in that era is provided in the 1591 draft of the Ratio, which includes a curious admonition8 directed toward university administrators to make sure that philosophy teachers do not disparage the dignity of mathematics. This rule concludes with the astute observation, "for it often happens that the less one knows about such things, the more he devalues them."9

THE VISION OF CHRISTOPHER CLAVIUS, S.J.

Father Christopher Clavius was professor of mathematics at the Roman College for about 45 years, from 1565 until his death in 1612. He saw the value of mathematics and did not feel himself bound by the Aristotelian categories that gave it a relatively low place in the hierarchy of academic disciplines. In contrast, Clavius wrote: "Since...the mathematical disciplines in fact require, delight in, and honor truth...there can be no doubt that they must be conceded the first place among all the other sciences."10 This predates Gauss' statement that "mathematics is the queen of the sciences" by about two centuries!

Around 1580, Clavius authored two documents, probably written for the commission charged with composing the first, 1586 Ratio.11 The impact Clavius had on the various versions of the Ratio cannot be underestimated. He had done significant scientific and mathematical work, his work in revising the Julian Calendar being only one example. And he proclaimed the importance of mathematics in the face of an academic culture in Italy and professorial colleagues at the Roman College who apparently demeaned mathematics whenever possible. Clavius saw new uses for mathematics in ways that were only beginning to be discovered in the last decades of the sixteenth century. He wanted to make sure that Jesuit schools placed proper emphasis on mathematics, by recruiting and training qualified instructors of mathematics as well as by requiring that mathematics be studied by all. Clavius' daring proposals are now viewed as revolutionary.12

We should also recall that the Jesuit mathematician Matteo Ricci studied under Clavius in Rome about ten years earlier13 and in 1586 was actually using his mathematical acumen to gain credibility in China, initially by translating two of Clavius' mathematical books into Chinese. Thus, at the same time mathematics was demeaned by philosophers in Italy, mathematics and astronomical technology became the doorway by which Ricci was able to gain entry into the culture of China.14

I suggest that Clavius' insight about the importance of the mathematical sciences, incarnated in the first Ratio, is a model for how we approach teaching technology in Jesuit schools in the next century.

ROLE OF MATHEMATICS AND TECHNOLOGY

When the *Constitutions* list the subjects taught in universities, it says, "Logic, physics, metaphysics, and moral philosophy will be treated, and also mathematics, in so far as they are in accord with the end proposed to us."15 The Latin reads "et etiam mathematicæ. "The presence of the etiam seems to give an added emphasis, as if one would not normally expect mathematics to be taught at a university.

The general norm found in the Constitutions about what should be taught in universities is this:

Since the end of the learning which is acquired in this Society is with God's favor to help the souls of its own members and those of their neighbors, it is by this norm that the decision will be made...as to what subjects [Jesuits] ought to learn....16

The thrust of Ignatius' thought seems obvious: Any discipline, including scientific, and therefore technological disciplines, which "help[s] souls" and "by their own nature help toward the ...ends" envisioned in the Constitutions, is worthy of study in a Jesuit university.17

Early Jesuit education was innovative in introducing into universities the study of mathematics alongside philosophy and physics.18 Especially in the first 1586 Ratio, mathematics was presented as a key to understanding physical reality as well as the model of correct rational procedure.19 But merely prescribing that mathematics be taught in a Jesuit university did not eliminate all the anti-mathematical prejudices of scholars from other disciplines.20

Since mathematics is an abstraction, it does not directly solve societal or spiritual problems. But, mathematics trains the mind to think in disciplined, structured ways, offers insights into the diversity of creation, and provides the language for the world of science and technology. Following Galileo, one can even consider that the "book" that is the universe "is written in the language of mathematics."21 Thus, in its own way, it contributes to the common good and to improving our global society.

MODERN TECHNOLOGY AND CONTEMPORARY JESUIT HIGHER EDUCATION

Unlike the debates about mathematics in the sixteenth century, today there is little disagreement about the appropriateness of disciplines such as computer science or engineering being offered in a university or about their academic stature. Centuries ago, the Church seemed to be an enemy of science and technology, with the condemnation of Galileo in the seventeenth century and the more recent prohibition of railroads and gas lights in the papal states by Gregory XVI in the early nineteenth century.22 But in the twentieth century, the Church has taken a significantly different approach.

Perhaps it was John XXIII who introduced the new emphasis when he wrote:
The progress of science and the inventions of technology show above all the infinite greatness of God...And since our present age is one of outstanding scientific and technical progress and excellence, one will not be able to...work effectively from within unless he is scientifically competent, technically capable, and skilled in the practice of his own profession.23

The recent Apostolic Constitution, Ex Corde Ecclesiæ, speaks to the work of Catholic universities in the fields of science and technology.24 The current existence of a Vatican web site and of Catholic programs on television and radio is a welcome sign that the Church has embraced technology to help spread the gospel message. The Ignatian tradition of "finding God in all things," even in technology, is accepted without debate today. Thus, perhaps the more important questions deal with the opportunities and challenges that studying technological disciplines presents to Jesuit schools and their students. And in a world in which science and technology are commonplace, leadership in tomorrow's world demands familiarity with technology and with the ways it helps or harms human progress.

Today's technology provides opportunities never before possible in our world. The early Jesuits saw education as a way to transform society, and the Ratio provided structures to provide an excellent education. In a sense, including mathematics in the Ratio forced Jesuits and their students to become familiar with this foundational language used by intellectuals of a world on the brink of what we now call “the scientific revolution.” Through mathematics, Jesuits and their students became engaged, perhaps unknowingly and unwillingly, with a culture that was only beginning to make its influence felt, the culture of Galileo and Newton, among others. Today, Jesuits and their students can again become engaged with a new culture, the culture of technology and the Internet, through knowledge of computers and technology.

The accessibility of modern technology enables Jesuit education today to continue the tradition of transforming society and engaging culture in new and exciting ways. In North America, Jesuit universities are finalizing plans for a common distance learning program, in which students do not have to be present physically at a university to take a course. There are already several accredited American universities that are completely online. Who knows how education will change as technology develops? Such developments offer the Society of Jesus opportunities for sponsoring new modes of education as well as a challenge to do it well. It is entirely possible that in 10 years there will be several virtual Jesuit universities, all run from computers housed in closets perhaps at the Jesuit Curia in Rome, or at a community in Manila or Kraków.25

There is also a great benefit in Jesuits’ using their computer expertise to promote spiritual growth. Creighton University’s web site on spirituality has had a tremendous impact since its creation in 1998 as well as the Irish Jesuits’ Sacred Space web site. The Society could sponsor an academic electronic journal on the Spiritual Exercises, accessible to anyone on the planet—much cheaper and reaching a wider audience than paper versions, and keeping with the Ignatian principle of having an impact on more people.26 We must also not limit our vision based on today’s technology, much of which has been around for only about ten years and may be hopelessly obsolete in ten more years. What the technology of 100 years from now will enable Jesuits to do is anyone’s guess!

I suggest that the Ratio provides insights that can still be applied when making decisions about new disciplines, especially technology, in contemporary Jesuit schools.

One insight deals with the need to study new disciplines, even if their stature is controversial. The vision of Clavius found in the preliminary Rationes was that mathematics was so necessary that everyone should study it for at least a year and a half, and that some should study it in greater depth. I suggest that a similar regulation is desirable for technology today..27 The spirit of the Ratio demands that all students enrolled in Jesuit schools become familiar with technology as a self-contained discipline as well as learning how to use technology as a tool for information and communication, since such knowledge brings them into intimate contact with today’s culture.

A related insight is that Jesuits themselves need to be trained in new technical fields. To my knowledge, I am one of only three American Jesuits with doctorates in computer science. The early Rationes went against academic culture in recommending that Jesuits learn mathematics. Perhaps we must do something similar today and do it quickly, for some have already suggested that in the use of technology and the web, we are doing “too little, too late.” It is a tribute to the early Society that over 30 lunar craters are named after Jesuit scientists.28 Can we regain that tradition in the next century?

Another insight deals with public presentations of mathematical topics. The Ratio recommended regular lectures, perhaps similar to a "colloquium series" at American universities, in which mathematical topics are presented, even by students,29 with those present questioning the presenter, even suggesting alternative proofs.30 The early Rationes suggested showing how mathematics is useful in the arts or in daily lives, and similar topics could also be included in lectures about new technologies.31 I recommend that such lectures on technological topics become a regular feature in our schools.

A fourth insight deals with the creation of a private "academy," that is, a study group for more capable students.32 Particularly in technical and scientific fields, which many students find difficult, smaller groups of students, special seminars, or honors classes can be taught aspects of an academic discipline inaccessible to the general student population.

A final insight is the need to respect the integrity of every discipline. Although the *Rationes* stressed the pervasive usefulness of mathematics, they also ordered that no one should speak disparagingly about a subject unknown to him. I suggest that this insight means that Jesuit schools should be places where basic scientific and technological research is honored and encouraged, even if the field does not seem immediately practical. It is contrary to the Society's tradition of the magis to teach or become involved in sciences and new technologies only half-heartedly!

The Ratio also provides us with challenges as well. Scientific and technical expertise divorced from a vision of a better world is hollow knowledge. We must never fear scientific progress, but we must also never let science become our masters and we its slaves! Technology, like the Church, is a reality which is semper reformanda. That on-going change puts an added demand on those who teach and attempt to learn tech- nology in ways most other academic disciplines do not.

There are ethical and societal questions raised by technology for which, even now, the world seeks answers, and Jesuit schools provide privileged places for experts in ethics, theology, science, and technology to share their thoughts on the what and how as well as the why and what for. We also must address questions about a new elite and a new poor that are raised by the access and lack of access to technology and the information it provides. There is also the danger of students' allowing technology to think for them, rather than understanding technology to be able to improve it and our world.

THE PURPOSE OF HIGHER EDUCATION

I wonder what Ignatius and Clavius would have done if they had had the opportunity to educate and evangelize society electronically? That may be pointless speculation, but it does provide the seeds for our dreams about the future of Jesuit education.

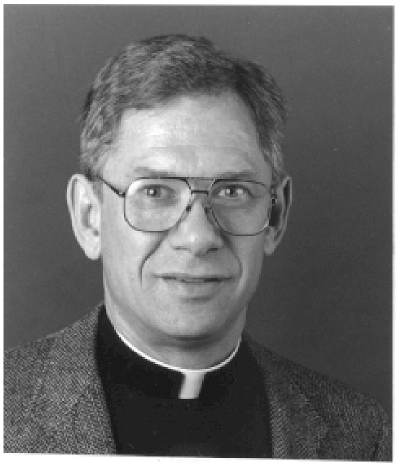
The purpose of education has developed over the centuries. In Roman times, education was seen to develop pietas, a reverential devotion to parents, the gods, and society. There was a moral aspect to learning and an implied duty to use knowledge to benefit society, following the thought of Cicero, who said "we are not born for ourselves alone."33

After the scientific revolution, the goal of education in many places shifted to discovering veritas, which is the one word motto of Harvard University. Truth itself is the goal, without any sort of connection to the self or to society.

I detect another stage that is becoming prominent today, namely, that education is utilitas, in the sense of being something useful and profitable for the self. I am actually surprised if I do not hear students ask questions about what type of job they can get if they choose to study a certain discipline.

It is easy for many students to become enamored of today's useful technology because it can lead to prestigious and well-paying jobs. Although I cannot eliminate this as providing some students with incentive for studying, I suggest that Jesuit schools also need to safeguard their ambience lest power and prestige seem to be the sole reason why Jesuits carry on their educational apostolates. The reason we teach and search for veritas is to develop in ourselves and our students pietas.

The Constitutions remind us that "the end of learning which is acquired in this Society is...to help the souls of its own members and those of their neighbors."34 Whatever helps build up God's kingdom on earth, whatever helps ensure that God's justice will prevail, whatever helps promote peace and unity among peoples and relieves pain, disease, and poverty, whether it involves the classics or the latest modern technology, that is what "helping souls" is about, and that is what Jesuit education in the next millennium is about as well.



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FOOTNOTES

1 See the introduction by Edward C. Phillips, S.J., to the translations of Documents 34 and 35 (of Clavius): "For a better understanding of some portions of these documents, it should be remembered that at that period `Mathematics' was a term including astronomy and much of what would now be taught in physics." Also, cf. Homann, p. 81, "...mathematics courses comprised not only arithmetic, geometry, and algebra, but also diverse use of mensuration and calculus in astronomy and astrology, computation of time (calendar and sundial), surveying, theory of music, optics (perspective), and mechanics."

2 On the Revolutions of the Heavenly Spheres (1543).

3 In 1582.

4 In 1633.

5 Mathematical Principles of Natural Philosophy (1687).

6 Dear, pp. 36-37; Homann, p. 5; Wallace, p. 136.

7 Homann, 81; cf. Dear, p. 35. The arts and humanities were only beginning to make their way into the universities, to be followed by the sciences as we think of them today.

8 Probably inspired by Clavius.

9 “fit enim sæpe, ut qui minus ista novit, his magis detrahat.” Ratio Studiorum, 1591, Regulæ Præpositi Provincialis: de mathematicis, n. 44; cf. Homann, p. 79, endnote 69.

10 Dear, p. 38, In disciplinas mathematicas prolegomena, in Opera mathematica, Vol 1, p. 5. Cum...disciplinæ Mathematicæ veritatem adeo expetant, adament, excolantque,..., quin eis primus locus inter alias scientias omnes sit concedendus.

11 Homann, pp. 61, 64.

12 Homann, p. 64; Feldhay, p. 221.

13 Ricci studied at the Roman College from about 1572 until 1577.

14 Immersion into and dialogue with culture is a contemporary Jesuit theme as well, cf. General Congregation 34, Decree 4, “Our Mission and Culture.”

15Part IV Chapter 12, [451].

16 Part IV, Chapter 5, [351].

17 Smolarski, p. 109-10.

18 Dear, p. 35.

19 Feldhay, p. 222. Thus mathematics serves the understanding of the physical world as well as of ultimate, i.e., metaphysical reality.

20 Cf. 1591 Ratio, rule 44 concerning mathematics of the Rules for Provincials.

21 Galileo, The Assayer (1623), cf. Drake, pp. 237-38. The pervasive nature of mathematics was emphasized in the 1586 Ratio influenced by Clavius whom Galileo knew. Cf. Wallace, pp. 91, 269.

22 Cf. Kühner, Encyclopedia of the Papacy, p. 225.

23 Pacem in Terris, Encyclical Letter, April 11, 1963, n. 3, 148. 24 August 15, 1990, Par. 7, 18, 45.

24 August 15, 1990, Par. 7, 18, 45.

25 Such universities could have excellent courses offered by an outstanding faculty selected from every physical Jesuit university and accessible to anyone with a computer, no matter where they live on our planet or even orbiting our planet. On the other hand, we should not ignore the possible negative effects of spending long hours before computers. cf. Carnegie-Mellon University, HomeNet Project, 1995, http://homenet.andrew.cmu.edu/project. But the benefits might be worth the risk.

26 ConsSJ [622-623].

27 It was only in 1995 that my own university approved a new requirement of at least one technology course for all students, even though personal computers had been on campus for ten years and the school is located in the middle of what is called “Silicon Valley.”

28 MacDonnell, pp.\ 74a, 74b, 76.

29 1599 Ratio, Rule 2 for the Professor of Mathematics.

30 1591 Ratio, Rule 3 for the Professor of Mathematics.

31 1591 Ratio, Rule 3 for the Professor of Mathematics; 1586B Ratio, De mathematicis.

32 Although the early Rationes made specific mention of an academy for mathematics, the same concept can be used for other scientific and technical fields as well.

33 Marcus T. Cicero, de Officiis, Book I, VII. 34 Part IV, Chapter 5, [351].

NEXT ISSUE

These days, we sometimes forget that women used to be pretty scarce at Santa Clara --- not an unusual situation for an institute of higher learning back in 1851. Women were first admitted as undergraduated in 1961, and their numbers quickly and significantly transformed the landscape of the University. But, as SCU historian, Gerald McKevitt, SJ., recounts in our next issue, the integration of women began many years ealier.

In our next issue, we will explore the role of women and gender at Santa Clara University and in the larger realm of Jesuit education. In addition to McKevitt's broad historical perspective, we will also feature brief memoirs from women who were among the first to attend SCU for an undergraduate degree in the early '60s.

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