Geomatics Curriculum Design Issues

Earl F. Burkholder

ABSTRACT: The purpose of this paper is to identify some of the factors that affect the practice of surveying and to look at the underlying issues, especially as related to surveying (geomatics) education.[1] As witnessed by this author, the surveying profession has undergone a dramatic revolution during the past 30 years, and modern surveying practice involves the use of technology only dreamed of a generation ago. As the role of surveying continues to evolve, surveying educators, perhaps more than any other, have both the opportunity and an obligation to insure the continued viability of our profession. Learning from the past, acknowledging the present, and looking to the future, the importance of a college education and curriculum design issues are considered in terms of:

- The historical interaction of surveying with engineering and other disciplines;
- The range of surveying activities including both technical and professional;
- The evolution of equipment and methods from transit/tape to GPS and computers.
- The transition from analog to digital and from 2-D to 3-D;
- Challenges and accomplishments with regard to ABET accreditation;
- The NCEES exams and the 4-year degree requirement for licensure;
- The broad scope of spatial data (geomatics) disciplines; and
- The role of geomatics and the focus of education.

Premise

The best thing I can do for my students is to help them learn how to learn and to recognize with them that learning is a two-way street.

Engineering/Surveying

I began working as a draftsman in 1968 for a consulting engineering firm engaged in land surveying, subdivision developments, municipal engineering, and other civil works. Surveying was an important part of that successful practice, and I naively assumed that surveyors and engineers everywhere worked together in such a symbiotic manner. Since then I have learned that surveying includes many other activities and I am comfortable with the following definition:

> Surveying is the generation, collection, storage, manipulation, evaluation, analysis, presentation, and use of geo-spatial data. Surveying also includes determination and demarcation of legal boundaries.

Such a definition is probably too broad but, in addition to traditional surveying activities, it accommodates the fact that geo-spatial data are digital and three-dimensional (3D). If an error is made in the definition, I would rather be guilty of making the definition too broad than making it too narrow. Incidentally, I also like the definition of surveying used by David King (Thurow and Frank 2001) who says "surveying is what surveyors do."

Earl F. Burkholder, PS, PE, NMSU Surveying Engineering Department, Las Cruces, NM 88003. E-mail: <globalcogo@zianet.com>.

Given the interaction of surveying with other disciplines (especially engineering), we need to look at other definitions as well. Consider the following:

> Let science be defined as the process of organizing knowledge such that conclusions are consistent with beginning assumptions and subsequent observations.

Since surveying involves measurements, observations, evaluation of evidence, and defending our conclusions, it is easy to say that surveying is a part of science. Science is often broken into two categories—physical science and social science. Physical science is that branch of science that deals with physical matter, forces, and pro-

[1] The views stated herein are mine and based upon 35 years of observation/participation. Like a blindfolded man describing an elephant, my views certainly reflect a bias. But I also admit that I have been peeking from behind the blindfold whenever I can. I have exchanged ideas with mentors, listened to colleagues, brain-stormed with students, read web bulletin boards, and browsed through many journals. I am overwhelmed by the thought of grasping the scope of geomatics education and still need help in understanding the issues. My intent is to give credit to others where due and to accept responsibility for any oversight or misinterpretation. For example, the summary by Greulich (2003) is particularly insightful and the follow-up discussion by McNichols (2003) contains food for thought. My goal is to put issues on the table and ask questions. Some answers may be quick and obvious, but others will emerge only after appropriate discussions.

cesses (hard science), whereas social science is that branch of science that deals with reasons for, and consequences of, decisions made by humans (soft science).

Whether physical or social, science is also categorized according to method of inquiry—theoretical or applied. Theoretical inquiry is conducted for the purpose of gaining a better understanding of the object or process of inquiry (called pure science). Applied science, on the other hand, is conducted for the purpose of finding or documenting that arrangement of elements or sequence of events that will produce a desired outcome (also called engineering).

For engineering, the definition given by ABET (Accreditation Board for Engineering and Technology; 2002) is probably more appropriate:

> Engineering is the profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind.

Notice that in the non-ABET definition of engineering the label "engineering" is assigned to a category of activities described as applied science. In contrast, the ABET definition of engineering describes activities one would expect to find or place in a box pre-labeled "engineering." In my opinion, the issue is not to debate which definition should be used, but to question whether we should attempt to define the practice of surveying and the practice of engineering as being mutually exclusive. Certainly, some people "do" engineering and some people "do" surveying, but it can also be argued that there is an enormous overlap between the two. Many people practice in both areas, and efforts to define one to the exclusion of the other are viewed as futile.

Given the overlap between surveying and engineering; both professions, as well as society at large, stand to benefit from a healthy, synergistic relationship. Although individuals in both professions can learn from, and build on, the strengths of the other, none of us is perfect, and we all need to be helped along at times. Instead of trying to build a reputation (personal or professional) on the foibles of others, we should promote collaboration and mutually beneficial interaction between individuals at all levels.

Technical/Professional

Surveying and engineering both include activities ranging from technical to professional. When looking at extremes, it seems easy to categorize a given activity as technical or professional. But, attempting to define "technical" to the exclusion of "professional" (or vice versa) is also viewed as futile, because of the overlap between these two categories. That being said, one problem to be aware of is that some engineers view the technical activities of surveyors as incidental and often fail to understand what it takes to provide such service. It is also true that some engineers understand new technology and implications of the digital revolution better than do the surveyors working for them. Regretfully, sometimes they too seem to enjoy rubbing it in. In either case, surveying is unfairly viewed as second-class by engineers.

The challenge for us in geomatics is to develop both the confidence and competence to interact with other disciplines (not just engineers) on an equal basis. Neither is it a one way street. Engineers are not the only ones who take others for granted. Surveyors also use (engineering) technicians in supporting roles and may fail to appreciate the talent required to provide such service. And, it is not uncommon for a surveyor (either a technician or a professional) to become indignant when working with a set of defective plans drawn up or signed by an engineer. I readily concede that this problem has been hashed and re-hashed but the point is, regardless of which side we find ourselves on, we need to be accommodating and willing to work with others to solve problems as they arise. Better communication goes a long way in establishing mutual respect and understanding. We also need to avoid unfair comparisons of technical activities in one discipline with professional activities in another.

Evolution of Equipment

The digital revolution has had an enormous impact on both surveying and engineering. In years past, surveying measurements were made using levels, Philadelphia rods, transits, steel tapes, theodolites, and subtense bars. Computations were performed using logarithms, trig tables, mechanical calculators, and a lot of paper. Plans were drawn at a drafting table using a parallel bar, T-square, mechanical pencils, India ink, Leroy guides, and generous amounts of "pounce" to keep the drawing clean. Archaic as that may seem, our ancestors made some excellent maps using those techniques and, even now, we can still admire their cartographic prowess.

In my lifetime, we have evolved to using electronic measuring devices, computers both in the office and in the field, photogrammetric and other remote sensing devices, and now GPS for an ever-increasing range of applications. Development of new measurement systems is continuing, as evidenced by the availability of reflectorless EDM, laser scanners, LIDAR, faster computers, greater sophistication in internet services, and the many applications of wireless technology.

Analog/Digital

The common denominator in the new measuring systems and applications is that spatial data are characterized as digital and three-dimensional (3D). In the past, a map was both the end product of a survey and the storage medium for the spatial information. The original map was filed in a tube or in a flat-file and stored in a vault. Copies of the map were hung on racks or folded up in manila folders and used reverently (or not). With apologies to the electrical engineers for borrowing the term, such maps are "analog." However, with the exception of photographic images stored on film or glass plates, most geo-spatial data today are stored in electronic files in a digital format. Thankfully, mass storage devices are also affordable, and we all have access to gigabytes of geo-spatial data at the click of the mouse. Using the stored information, a map can be generated at will by the user without altering or destroying information stored in the database. The map is displayed or printed for a particular use and often discarded. If needed, another copy of the map or view of the geo-spatial data can be generated, displayed, and/or printed on demand.

Although digital geo-spatial data are characterized as 3D, a flat map introduces an instant bias toward perceiving spatial data as two-dimensional (2D), whether in a plan view or profile view. The surveying and mapping professions have a long history of working with horizontal and vertical data separately. In part, it is because we walk erect and view location differently than elevation (Burkholder 2004). Another reason we have used horizontal and vertical separately is that they have two distinct origins. Horizontal data are related to the equator and Greenwich, England, for latitude and longitude (and ultimately to the Earth's center of mass), but vertical data have been associated with sea level. After all, sea level is an intuitive visible physical reference used worldwide. Databases containing horizontal and vertical data separately have been developed and utilized by many segments of the geo-spatial data community.

However, geo-spatial data are three-dimensional, and modern measurement systems routinely generate and collect 3D data. The global spatial data model (GSDM)[2] was developed to accommodate those characteristics. The GSDM, which has a single origin for 3D geo-spatial data and provides for the integration of modern measurement systems, electronic digital data, and data processing procedures, also supports the user's view of the world (Burkholder 1999).

Progress in ABET Accreditation

The Accreditation Board for Engineering and Technology evaluates the quality of higher education programs submitted to it for review. ABET was formerly known as the Engineers Council of Professional Development (ECPD) and reviewed programs under one of two commissions—engineering or technology. The ECPD became ABET in 1980, and the engineering-related commission was added in 1983. Since then, surveying has had programs evaluated by three commissions: the Engineering Accreditation Commission (EAC); the Technology Accreditation Commission (TAC); and the Related Accreditation Commission (RAC), which is now known as the Applied Science Accreditation Commission (ASAC).

[2] For those who do not know, my professional interest has long been applications of new technology to modern surveying practice. After teaching at Oregon's Institute of Technology from 1980 to 1993, I was self-employed until I went back to teaching at New Mexico State University in 1998. I took a sabbatical leave from Oregon Tech in 1990-1991 and spent most of the year at the University of Maine learning what I could from Alfred Leick, Ray Hintz and others. Dr Leick is the one who sparked by interest in 3-D and the work I've done on development of the GSDM is directly attributable to him. I know it is presumptuous, but I see the GSDM as an interoperability mechanism which can be equally useful to those who design and build geo-spatial measuring systems, the geomatics activities which serve both camps and spatial data users at all levels—even the flat Earth advocates. While I was self-employed, I began writing a book on the GSDM but when I went to NMSU, teaching became my first priority. Although I've made some progress on the book during the summers, I need a larger block of time to "finish the book." To that end, I have been granted a sabbatical leave from NMSU for the 2005-2006 academic year. For those interested in more details, a copy of the sabbatical proposal is posted at www.zianet.com/globalcogo/sabbatical.pdf.

Prior to 1984, surveying programs could be evaluated by either the EAC or the TAC. In cases where surveying was already part of an EAC program, seeking accreditation elsewhere was not really an issue. In other cases, surveying programs were accredited by the TAC. The problem for new or evolving surveying programs was that the EAC criteria were judged not flexible enough to accommodate curricular content specific to surveying, and TAC accreditation was judged by various state registration boards as insufficiently rigorous to count as four years toward licensure. After much discussion, ABET added the Engineering Related Accreditation Commission and two surveying programs—Ferris State and Oregon Tech—were evaluated in the fall of 1984. Industrial Hygiene, Safety, and Industrial Management programs are also now part of the ASAC.

Any program evaluated by ABET is judged according to the general criteria established by the relevant Commission and program-specific criteria developed by the member professional organizations. All criteria are approved by the ABET Board of Directors prior to being implemented. The American Congress on Surveying and Mapping (ACSM) is one of approximately thirty professional member organizations of ABET and has representation on the ABET Board of Directors. ACSM also has representation on each of the three commissions that accredit surveying programs, and it is responsible for developing surveying program criteria for each commission. In the early 1980s there were vigorous debates about the general criteria and the surveying program criteria to be implemented by the RAC. Several results of those discussions (Burkholder 1987) were:

- The criteria for surveying programs were to be just as rigorous as for engineering.
- The math component of the surveying programs was to be 15 semester hours beyond trigonometry, on a par with engineering.[3]
- The RAC surveying program criteria also required acceptable course offerings in five of the following six areas:
  - Field surveying instruments and methods;
  - Photogrammetric mapping/image interpretation/remote sensing;
  - Surveying calculations and data adjustment;
  - Geodetic coordinates and astronomy;
  - Cartographic representation, projections, and map production; and
  - Computer-based multipurpose cadastre, geographic information systems.

Given that ASCE and ACSM both have an interest in surveying programs, the surveying criteria are developed by ACSM, as the lead society, in cooperation with ASCE. Within ACSM (prior to the recent re-organization), the Curriculum, Accreditation, and Registration (CAR) Committee was the group that discussed and recommended surveying program criteria for surveying programs in all three Commissions. In the recent re-organization, the ACSM Education Committee was combined with the CAR committee, which is now known as the CARE committee. In addition to developing surveying program criteria, the CARE committee is also the group that trains and maintains a list of qualified surveying program evaluators.

Outcomes assessment was brought to the forefront in accreditation philosophy in the 1990s, and the ABET/EAC was the first Commission to develop and use outcomes-based criteria. They were known as EC2000. Since then, the other ABET commissions have adopted the outcomes assessment approach for evaluating all programs. As a part of that evolutionary process, the scope of both the general criteria and the program-specific criteria came under careful scrutiny. As a result, the general criteria for all commissions are now quite similar, and the program criteria were drastically reduced in all commissions. As surveying had programs in three commissions, ACSM and surveying representatives were lobbied heavily to make the surveying program criteria as nearly the same as possible between all three commissions. I was a member of the RAC Executive Committee when the RAC voted to adopt the new criteria. I remember a subsequent hallway conversation with a scientist from the National Institute of Health, who expressed concern that, with regard to surveying program criteria, the surveying profession "gave up too much" in the spirit of "going along to get along."

In this context, the following questions should be discussed:

- Now that outcomes assessment has been fully implemented by all ABET commissions, should the surveying program criteria in the three ABET commissions be re-visited? If so, what changes, revisions, or improvements are needed?
- The Geomatics Division of ASCE has over 3700 members. What steps can or should be

[3] Where Calculus I is considered the entry level math for an engineering program, the RAC general criteria consider entry math level to be college algebra and/or trigonometry.

taken to invite ASCE and members of the ASCE Geomatics Division to participate in discussions about surveying program criteria? Or is the cooperating status of ASCE for surveying program criteria unnecessary?

NCEES and Licensure

Eventual licensure of our surveying graduates is a goal that affects decisions about geomatics curriculum design. Given ongoing technological developments, recent changes to the National Council of Examiners for Engineering and Surveying (NCEES) Model Law, and the implementation of the Model Law by the various state boards, it is difficult to identify key issues with a high degree of certainty. From a generic perspective, licensure is based upon an acceptable (ABET-accredited four-year) degree and four years of experience acceptable to the board. When I took the surveying registration exam years ago, the first eight hours was the national NCEES Fundamentals of Surveying (FS) exam, while the second eight-hour exam was prepared, administered, and graded within the state. Of late, most states utilize the FS eight-hour exam and six hours of the NCEES professional practice exam. The remaining two hours are typically reserved for a state specific exam.

The FS exam has evolved from an exam focused primarily on practice (and apprenticeship) toward a curriculum-based exam more closely related to the courses and materials covered in a typical college curriculum. There is direct and specific correlation between theory, the knowledge base, and the FS examination. However, the professional practice portion of the NCEES exam still more closely reflects actual surveying practice. Pedersen (2004) writes that (with regard to both exams) "...practicing land surveyors essentially determine the examination content. The exams represent the collective experience of a broad spectrum of licensed land surveyors."

Given that the responsibility of each state licensure board is to protect the health, safety, and welfare of the public (against incompetent practice), it is understandable that the various boards are not going to champion the cause of, or base their policy decisions on, the latest "high-tech wizardry." However, as technical innovation invades professional practice, the impact of modern technology is appropriately included as part of the overall examination process. I am not suggesting a change in the way exams are prepared, administered, graded, and used, but I do believe the following deserve our vigilant attention:

- To what extent should the FS and the professional practice exams be tailored to curriculum content?
- Should those of us in academia ever yield to the temptation to develop or modify our curricula for the express purpose of helping the student to "pass the FS exam"?

Regretfully, these issues have been clouded by the practice of using student performance on the national FS exam as one of the metrics of outcomes assessment in the ABET accreditation process.

The Broad Scope of Spatial Data (Geomatics) Disciplines

So far, this discussion has focused primarily on surveying and engineering. However, if we embrace the broader definitions, we quickly realize that other disciplines come into focus as well. For example, the American Society of Photogrammetry and Remote Sensing (ASPRS) bills itself as "the imaging and geospatial information society" and the Institute of Navigation (ION) is a professional organization whose members include many persons who design, build, and operate satellite (and other) navigation systems. ASPRS and ION both support high-level technical meetings and publish scientific peer-reviewed journals. Many of their members are heavily involved in research and development, manufacturing, marketing, and operation of geospatial (satellite) measurement systems. Specific disciplines supporting such activities include aerospace engineers, electrical engineers, physicists, mathematicians, geodesists, and others. Typically, professional registration is not a priority or an issue because these persons rarely work directly for the public.

On the other hand, there is a much larger group of people in various disciplines such as fleet management, planning, environmental science, geography, and other location-based services that use geo-spatial data in a variety of applications. The common thread here is the use or application of a Geographic Information System (GIS). Jack Dangermond of ESRI, probably more than any one person, has popularized the use of GIS all over the world, and ESRI training/marketing activities are successful almost beyond imagination. Is GIS a profession the practice of which should be licensed or certified or should GIS be considered merely a tool that can be used by anyone at any of the various levels of technical sophistication? Although no attempt is made to address them here, several points could be made about the spatial data research being conducted at the University of Maine (McNichols 2003) and other places (Egenhofer and Golledge 1998).

The Role of Geomatics and the Focus of Education

Given the broad scope of generating and using spatial data, what is the appropriate role for geomatics, and what are the implications for our various educational programs? ACSM has published numerous articles in the past several years about surveying education. It is certainly beneficial to share experiences and learn from each other (especially in this surveying educators conference), but have we really identified what it is we do and how our efforts fit in the broad spectrum of geomatics? Of course we have. We should all be proud of what we do and the contribution we make. This notwithstanding, have we really identified our strengths and shown others why surveying is an essential part of the spatial data spectrum? Several excellent examples of a good start include a web slide presentation posted by Ghilani (2005) and the ACSM/NSPS (2005) educational kit, but I am convinced we need to do more. Can we imagine a successful campaign of marketing the benefits of geomatics knowledge and services to the extent that the enrollment problems in all of our programs disappear and we all have more students than we know how to handle?

Think about it for a minute. On one hand there are the scientists and manufacturers who build and support measurement systems. Products range from sophisticated satellites orbiting the Earth to GPS chips embedded in an ever-increasing range of devices. Their job is largely completed with the delivery and support of a plethora of measurement systems used by a wide range of people from expert to novice. On the other hand, there is a much larger group of users who employ spatial data technology in many ways. Many GIS users have no desire to understand the intricacies involved in generating reliable spatial data and prefer to start with the spatial data provided by others. For some it may be the coordinates for the control points in the NGS database. For others it may be digital files downloaded from the USGS, and for yet others it may be parcel maps that have been digitized by the local county office. And some will take their own GPS units to the field to obtain the data they need. Stories abound about naïve users who did not ask for help when they needed it. Should those be seen as an opportunity to market geomatics education? Let us examine some of the following points in this respect:

- Although they may be very sophisticated, only a small portion of those "big picture" activities require the service of a licensed person. Furthermore, there many spatial data activities that are "technical," and many people employed therein enjoy satisfying careers without the need or desire for licensure.
- Some persons (by choice, necessity, or both) may function equally well in both the "generating" and the "user" camp. But, specialties being what they are, most persons, except those in geomatics, work in one camp or the other.
- Geomatics can be viewed as bridging the gap between the scientists and manufacturers who build highly sophisticated measurement systems and the spatial data user community. Of course, that is an oversimplification until we introduce the issues of licensure and professional accountability. With our responsibility for protecting the health, safety, and welfare of the public, we have an obligation to society to understand both sides because they relate to and impact one other.
- Should our geomatics programs be so heavily focused on eventual licensure that we fail to recognize the opportunity to serve other portions of the geomatics career spectrum? Would there be any advantage to designing a multi-track program, one of which is accredited for eventual licensure, so that we might attract more students? I'd like to see geomatics programs become the educational track of choice for many persons preparing for employment in a spatial data discipline.

Conclusion

Surveying is a diverse profession, and many forces have brought us to where we are—professionally. Some influences are beneficial and others are not. The professional status and prestige we enjoy today were achieved through the dedicated efforts of many persons, both individual and collective. It is also true that some conditions exist today in spite of our wishes or best efforts. Some undesirable circumstances lie within the realm of things that can be changed, while other circumstances are thrust upon us, and our only recourse is to adapt. Some things will not happen unless we make them happen and other things will never be achieved, no matter how hard we try. That said, we owe it to ourselves, out students, the professions, and society at large to take a broader look at surveying education in the U.S. and to design these programs such that they remain the education of choice for anyone anticipating an exciting career in geomatics.

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