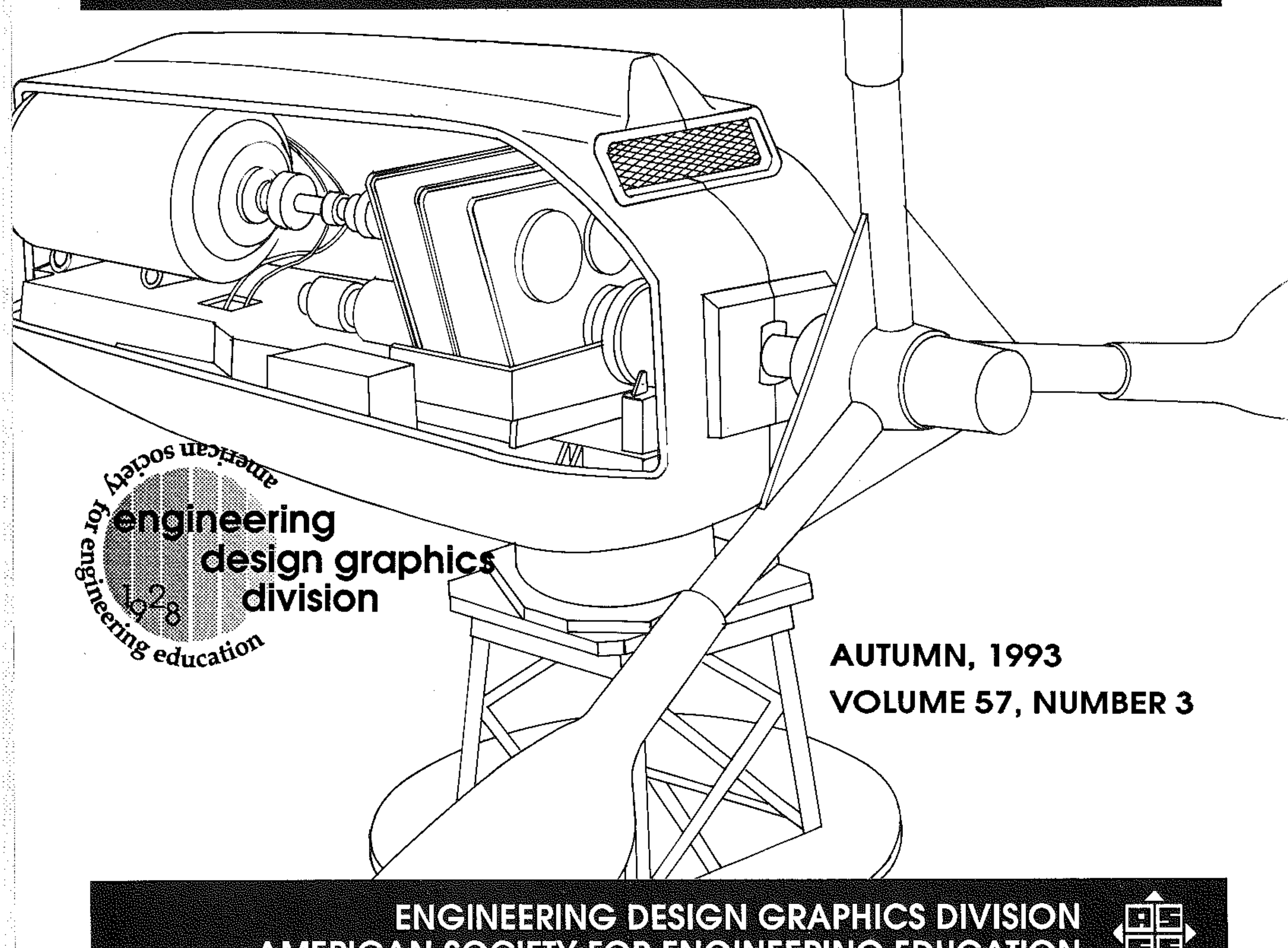
THE ENGINEERING DESIGN GRAPHICS JOURNAL



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ENGINEERING DESIGN GRAPHICS DIVISION
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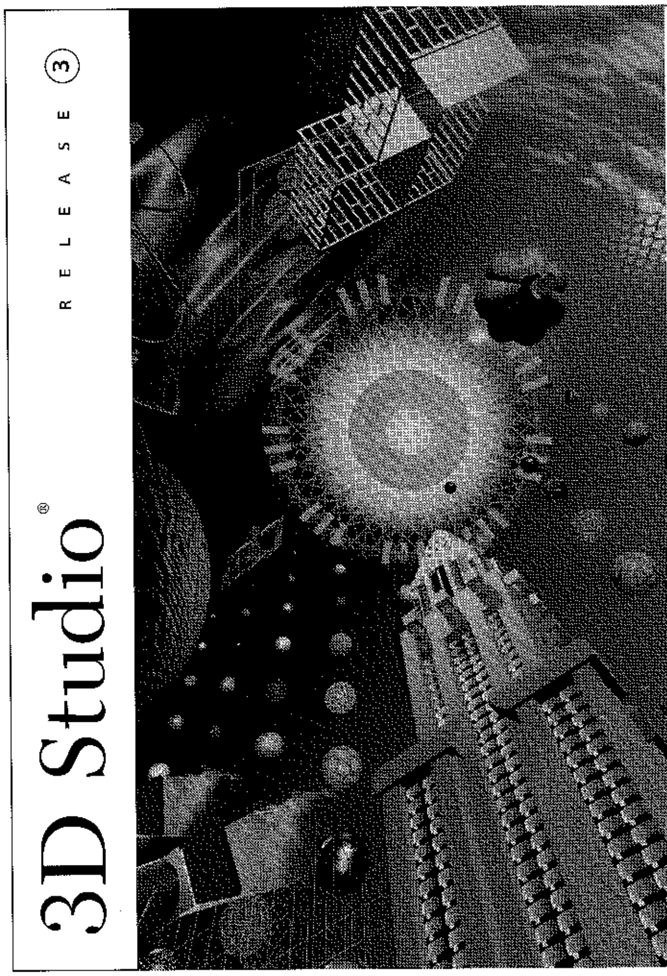

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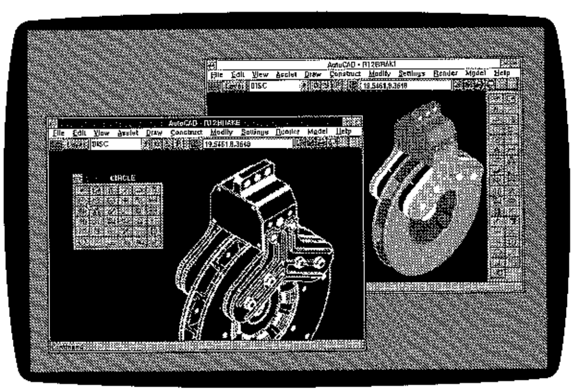

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THE ENGINEERING DESIGN GRAPHICS JOURNAL

Volumn 57 Number 3 Autumn 1993

The *Engineering Design Graphics Journal* is the official publication of the Engineering Design Graphics Division of ASEE. The scope of the Journal is devoted to the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics in an effort to (1) encourage research, development, and refinement of theory and applications of engineering design graphics for understanding and practice, (2) encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses, and (3) stimulate the preparation of articles and papers on topics of interest to the membership. Acceptance of submitted papers will depend upon the results of a review process and upon the judgement of the editors as to the importance of the papers to the membership. Papers must be written in a style appropriate for archival purposes.

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. . . from the EDGE

Engineering • Design • Graphics • Editor

One of the things that we at Purdue have recently been discussing, looking into, and getting ready to teach is a course on Multimedia. Since as a grad student I had helped teach a course on multimedia, I foolishly thought that I had a pretty good understanding of the multimedia concept. Silly me. The more we as a staff talked about multimedia the more confused I became. It wasn't until Gary Bertoline started passing around multimedia books for us to review as possible texts for the course we will be teaching this spring, that I began to understand. The book I took to review was written by Tay Vaugn, and is called *Multimedia: Making it Work.* It was published in 1993 by McGraw-Hill. It didn't take long to clear up my confusion. In fact, the first sentence of **Part One, Chapter 1** goes like this. "Multimedia is any combination of text, graphic art, sound, animation, and video that is delivered by computer." (Vaughan,1993)

That one sentence cleared away all the confusion that had been troubling me. Now I understand, because in order for something to be multimedia, it must be delivered by the computer. All those presentations, combining, sound, text, video, and whatever else was available, was not multimedia, because it was not delivered on the computer.

Now I ask you, what is happening here? Because the computer, actually the PC, is now capable of doing more and more, we now have a new and exciting field called multimedia? I hate to disappoint a lot of you computer gurus, but multimedia has been around for a long time. People in education, sales, and training have been producing multimedia presentations for many years. True, they had to work with a variety of different methods including the tape recorder, video, movie camera, still camera, and overhead projector. Now, because the computer is capable of combining sound, sight, and motion into the same machine, it does not mean that we have invented a whole new field, it simply means that we have new methods.

Do you remember when the movies first became available for educational purposes? There was some debate about whether or not the actual teacher would still be needed or if educational movies would become the major deliverers of instruction in our classrooms. Well, movies have given way to video, which is now giving way to computers, and we still have (and need) teachers in our classrooms. Let's not get carried away with our computer arrogance and suggest that what we are doing is a totally new and better approach. Let us not forget that the computer is a tool. It may make our lives easier, but so far, most of what we are doing has been done before. It might have taken longer, and been slightly cruder, but we are not inventing the wheel with computer multimedia, we are simply using the newest tools available.

Mary A. Sadowski, **Editor**

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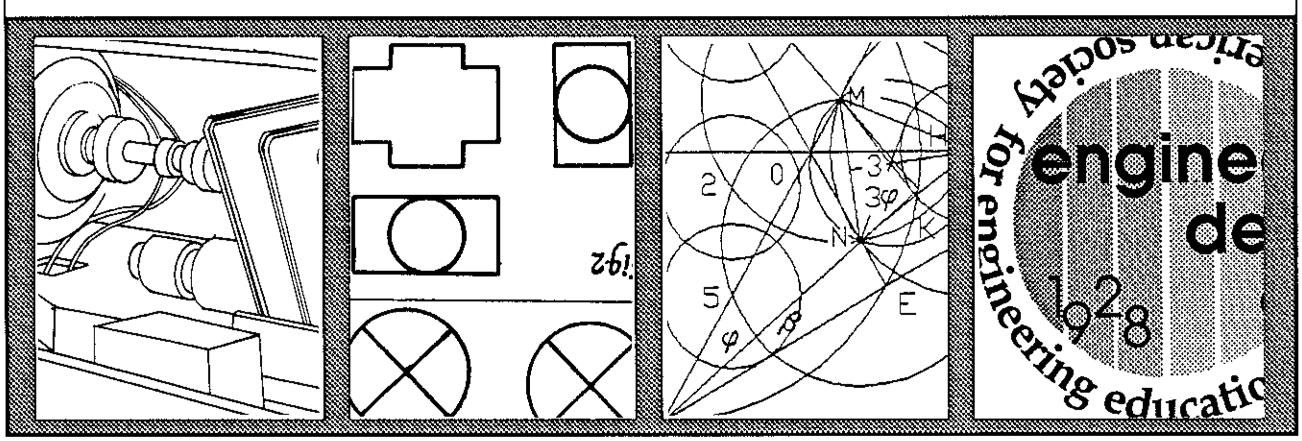

A Structure and Rationale for Engineering Geometric Modeling

Gary R. Bertoline
Purdue University
West Lafayette, Indiana USA

> There is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new order of things...
>
> Niccolo Machiavelli
> *The Prince*, 1513

ABSTRACT

This paper proposes an engineering graphics curriculum model by first categorizing human knowledge, then subdividing it into more manageable divisions. In this way a knowledge base for engineering design graphics is defined and logically organized. The major conceptual features of graphics knowledge is outlined to define a new paradigm used to develop engineering graphics curriculum content. This technique resulted in a more refined definition, logical place, and philosophical foundation for the existence of graphics in engineering education. The model was developed so that the subject matter could be grouped into more functional and manageable divisions useful when developing curriculum. Finally, a name change is recommended to reflect the paradigm shift and resulting curricular modifications.

Statement of the Problem

Major curricular changes are necessitated out of internal and external forces which directly affect current methodologies. There are at least three major forces at work which make curricular change in engineering graphics imperative:

1. Changes in engineering design documention,
2. Changes in the engineering design process,
3. Industry and education access to 3D computer modeling software.

Changes in Engineering Design Documentation

The formal teaching of engineering graphics in higher education began at the Ecole nationale des Ponts et Chaussees in France around 1750. One of the first drawing courses established in the United States was at West Point in 1803 followed by descriptive geometry taught in 1816 by Claude Crozet (Ross & Ross, 1992). Since that time engineering graphics has been heavily influenced by the needs of industry to produce engineering drawings for production. Standards became more prominent and were integrated into engineering graphics. Early textbooks reflected the heavy emphasis of standard drawing practices as an important component of engineering graphics instruction.

The seminal text *A Manual of Engineering Drawing for Students and Draftsmen* by Thomas E. French published in 1911 by McGraw Hill reflects the emphasis on drafting. The forward for the text states: "It is a full, well rounded treatise, designed to give a sound training, and it is a useful book to every draftsman in later professional work." The emphasis in engineering graphics instruction was on **drafting** practices and skills. Many of the later texts were modeled on French. What is remarkable is that the French text and others like it still reflect the emphasis on drafting and are still in use today. Yet most engineers in industry today are not expected to be skilled drafters. They should know how to read engineering drawings and create sketches and computer geometric models but drafting skills are no longer important. The engineering curricula and the engineering profession has shown significant changes in the last 30 years (Pleck & Bertoline, 1990). The same cannot be said of engineering graphics.

The professional organization representing many of the engineering graphics professionals in the United States is the Engineering Design Graphics Division of the ASEE (American Society for Engineering Education). This division changed itsname by adding the word *design*. The name changed in 1967 to Engineering Design Graphics to reflect the interest in design in engineering education. However, did anything significantly change other than the name? Was there a real paradigm change from engineering graphics standards and documentation practices to the representation of engineering design using graphics? Many engineering graphics courses changed only their name. The real content of the courses still emphasized engineering graphics standard drawing practices.

Two recent studies have had a major impact on engineering design graphics curriculum content. The NSF (National Science Foundation) study concluded that a modern engineering graphics curriculum must be centered on solid modeling. (Juricic & Barr, 1990). The SIGGRAPH study recommended that engineering design graphics curriculum be focused on the body of knowledge relveant to the discipine and not be tool bound. (Bertoline, et al, 1990). Both studies aknowleged the importance of computer modeling and the decline of importance in traditional 2d documentation. By creating a 3D model of a design, 2D documents can be nearly automatically produced from the model. In addition the 3D model is used for engineering analysis and for production.

Changes in the Engineering Design Process

Modern design, analysis, and communications techniques are changing the traditional role of engineers. Engineers must be able to work in teams, design, analyze, and communicate using powerful CAD modules and possess a high degree of visualization ability.

The design paradigm in U. S. industry is shifting from a linear segmented activity to a team approach involving all segments of the business using computers as the prominent tool. World class comapnies are restructuring their engineering processes to implement concurrent engineering. (Giffi, et al, 1990).

In many industries design engineers work in teams to create conceptual designs using sketches, computer models for visualization and analysis and then doing minimal documentation for production. Documentation may be in the form of 3D computer models sent directly to production to generate the CNC (computer numerical control) code for machining, and 2D drawings extracted from the 3D model with critical dimensions added for CMM (Coordinate measuring machine) checking for quality control. One major aircraft manufacturer in the U. S. has their engineers translate 3D CATIA models into a Macintosh format where it is used to create Hypercard stacks for assembly instructions. These instructions are then used by the technicians as an aid to assemble the craft. The trend in U. S. industry is for engineers to be expert geometric modelers using computers. There has been a basic paradigm shift in the way engineering design is performed in U. S. industry.

This paradigm shift has resulted in changes in the way engineering design documents are used. Engineers and technologists are finding that the sharing of technical information through graphical means is becoming more important for both the technologist and individuals from diverse occupations as shown in Figure 1. The trend of sharing technical information is increasing among all fields because computer graphics has the ability to simultaneously communicate many kinds of quantitative, verbal, and visual information. Computer graphics also tends to draw together many individuals with various visual needs and abilities.

Large diversified groups are able to communicate faster and more efficiently through graphics, especially computer graphics. The numerous devices, methods and media are driving the need for broader visual communication skills that were seldom necessary for engineers and technologists of the past. The need to understand principles of visual communication is a global need that includes engineers, scientists, managers, and technologists.

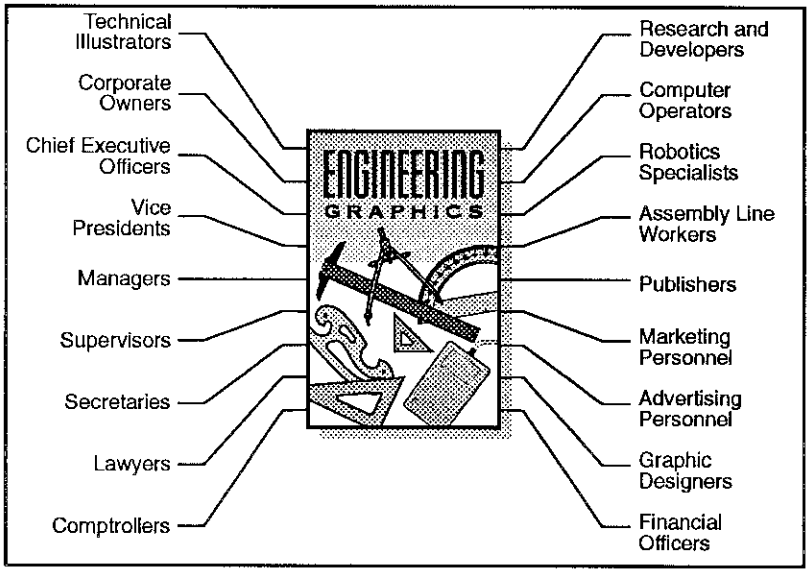

Figure 1. Common Users of Engineering Graphics

Access to 3D Computer Modeling Tools

Both industry and education are finding that 3D computer modeling tools are available at reasonable costs. It is now possible for industry and education to follow the lead of progressive companies who have made the design paradigm shift. Access to 3D computer modeling means that higher education can begin major curricular changes to adequately prepare engineers for the future instead of the present or past. Engineering design graphics curricula now have access to the tools necessary to prepare engineers to be geometric modelers and not drafters, or blue print readers.

A Framework for Engineering Graphics

A paradigm is the conceptual lens through which curriculum problems are perceived (Schubert, 1986). Paradigms form our frame of thought and dictate what we see. The conceptual framework shape the curriculum and form a basis upon which to accept some forms of evidence and to reject others. The paradigm sets the boundaries then establishes how to be successful in solving problems within those boundaries. There are at least three important frames of reference used to form the new engineering graphics paradigm which will be used as a basis for the proposed curriculum model:

1. visual science as the source of the subject matter,
2. engineering design graphics is applied to the design process, and
3. new subject matter boundaries within the discipline.

Visual SCIENCE

All types of graphics could be placed under the general heading of visual science. Visual science is the formal discipline of visual knowledge, laws, and methods obtained by study, practice, and scientific verification. (See Figure 2). Although graphic science may be a more common term, it is seen as too limiting and visual science would better describe the body of knowledge. This discipline is grouped with the sciences in human's secondary knowledges. Science is defined as the organization and explanation of human and natural phenomena in a systematic and logical manner.

In the past, the visual sciences have been an eclectic group of related subjects. Universities divide knowledges into various disciplines and form colleges, schools or departments for those disciplines that have common needs, such as a school of science. Normally the graphics disciplines are scattered throughout the university. For example, graphic design departments are sometimes located in the school of art,

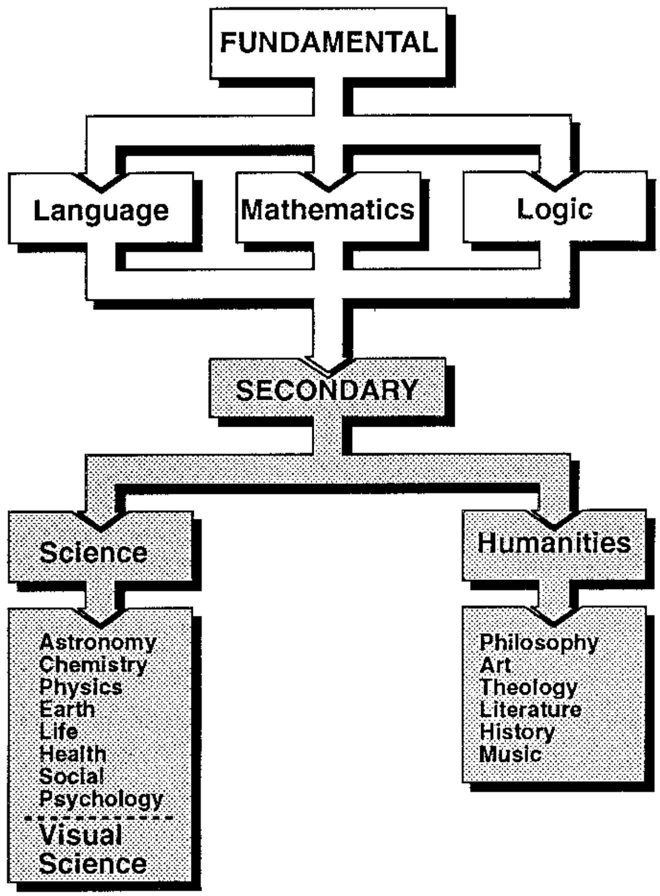

Figure 2. Domains of Knowledge

engineering graphics in schools of engineering or technology, and so forth. Even when specific graphics disciplines are placed in departments of their application, such as engineering, the subject and the faculty are viewed as being somehow different from the rest of the faculty and discipline. Graphics is recognized as important in engineering, technology, and the arts but not on the same level as other disciplines within that school. It is time to recognize that there is a significant body of knowledge related to the visual disciplines and engineering design graphics is a part of it.

There are three major components to visual science: visual perception, optical science, and graphics. (See Figure 3). These three components are the subject of visual science and are the core areas of research for the discipline of visual science. **Visualization** is the process of mentally comprehending visual information. (Wiley, 1990). **Optical science** is the study of the human vision system. Optical science would be studied as it relates to the cognitive visualization process. Although optical science may not be viewed as a relevant area of research or study there is direct application for it in engineering graphics. (Makino, Et al. 1992). **Graphics** is a visual communications language incorporating text, images, and numeric information. Graphics can be the more traditional types of representations such as engineering drawings, computer models such as a solid model of a mechanical part, the virtual reality displayed within the goggles of a virtual reality system or the graphical display of scientific data. Visual perception, optical science, and graphics comprise the areas of research relevant to engineering design graphics.

Visual perception, optical science, and graphics form the backbone of the subject matter of visual science. From visual science comes the knowledge base for all graphics courses including the needs of the learner and the subject matter, two of the three important inputs when developing curriculum. (Tyler, 1950).

Therefore, the first frame of reference is that there is a distinct body of knowledge called visual science from which much of the subject matter of engineering graphics is derived.

Technical Applications of Visual Science

Sciences are not concerned with the application of knowledge but with the finding of new knowledge. However, all sciences can be applied to various human wants and needs. The visual sciences can be applied to two broad design disciplines: artistic and technical. Artistic design is performed by artists and technical design is performed by engineers, technologists, and industrial designers. **Artistic design** is the conscious production or arrangement of color, form, and other elements that affect the sense of aesthetics. The main purpose of art is for personal expression and not to solve some problem using technical means as engineering design does.

The engineer is concerned with the relevant components of visual science related to the engineering design process. The primary purpose of the technical application of visual science is to communicate. **Technical communications** is a product of a technical process, such as engineering design, that consists of text, images, and numerical information.

Engineers are creative people who use technical means to serve human wants and needs. Engineers apply scientific and mathematics principles to a problem. Engineers are concerned with the processes of design, production, and servicing of a product or structure. These processes are communicated, analyzed, and documented using technical communications methods called engineering design graphics.

Therefore, the second frame of reference is that engineering design graphics is a visual science applied to the technological processes of designing, planning, producing, and servicing a product, process, or structure.

Broadening the Engineering Graphics Curricula

Today's computer graphics tools are blurring the lines between many subjects within technical graphics. The real question is whether that blurring translates into significant changes for a traditional engineering design graphics curriculum. To ignore the blurring is to ignore the inevitable technological progress in computer graphics. Engineering graphics must make some adjustments and accommodations for the blurring of traditional lines between subjects. Traditional engineering graphics departments should focus not only on engineering design but expose students to the related areas. Students should have some experience with computer engineering analysis techniques, CAD/CAM, scientific visualization, computer rendering, computer simulation, desktop publishing, and other related areas. Students should experience how the initial computer data base and computer graphic representation of the design are used throughout the engineering design, production, sales, and maintenance of a product or structure. All these processes can use the 3D model as input for the graphical product.

A new method of doing engineering also is emerging. Traditional engineering design was a linear process that would create a design with little or no input from manufacturing, marketing, and the customer. That is now changing as successful U. S. companies able to compete in a world market are using concurrent engineering. **Concurrent engineering**, sometimes called simultaneous engineering, is a nonlinear product design process that includes all the people and processes necessary to produce a product working concurrently as a team. (See Figure 4). This is a significant change in the design paradigm from a segmented linear activity to a holistic team approach. Designs are no longer thrown over the wall to manufacturing. Concurrent engineering depends on the active use and sharing of a 3D computer geometric model. Three-dimensional geometric modeling through the use of wireframe, surface, and solid modeling techniques is the way modern engineering design and production is done or will be done in industry.

Therefore, the third frame of reference is that engineering graphics must reach beyond traditional boundaries for the content of its subject matter, and be based on 3D modeling while still focusing on the graphic communications of engineering design, production, planning, sales, and maintenance of a product or structure.

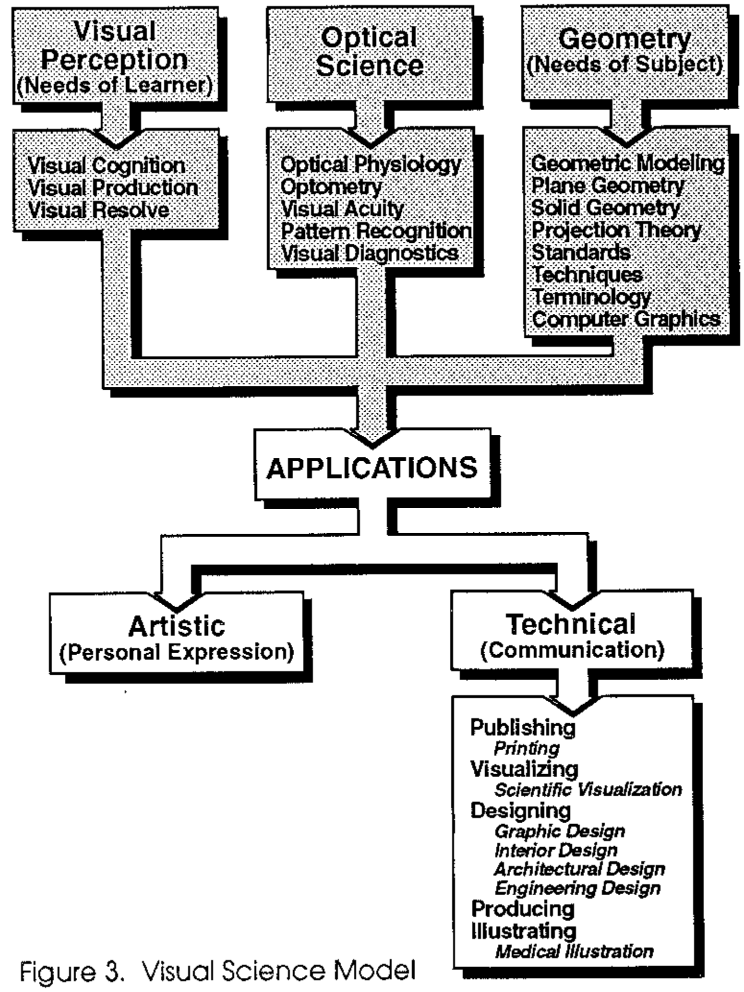

Figure 3. Visual Science Model

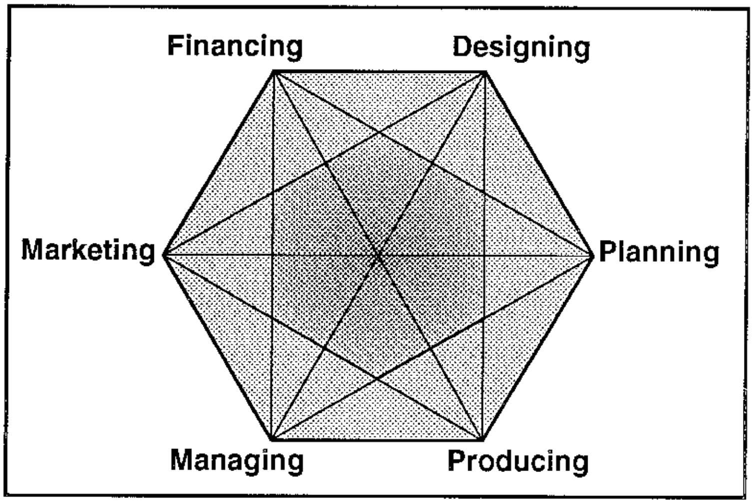

Figure 4. Concurrent Engineering Model

Changing the Name to Reflect the Change in the Paradigm

As related earlier, engineering design graphics was a name adopted by many in the late 1960's. This was preceded by the name engineering graphics. The name engineering graphics implies that graphics is used by engineers for some purpose. That purpose was design which was appropriately added to the discipline's name. The current name makes sense to many in the discipline because they understand what it means. However, the perception by those outside the discipline may be very different. The word *graphics* has strong negative connotations in higher education. Many of the current engineering faculty and administrators came from an era when engineering design graphics meant learning drafting practices. Graphics to them is 2D drawings on paper which many find irrelevant in engineering education.

Arguing whether the perception of others is right or wrong serves no useful purpose. Perceptions and attitudes are very hard to change and that change is a slow process. The reality is that the word graphics to many means 2D. Engineers now work with 3D virtual computer models. It could be argued that good visualizers always worked with 3D virtual models but that would miss the point. Modeling by virtue of the computer is a reality and is a more accurate description of what an engineer does with a computer. An engineer does not produce graphics for the sake of creating images. The graphics are a by-product of the computer modeling process. Engineers are geometric modelers who craft design ideas using computer graphics.

It may be time to seriously consider changing the name we use to describe our discipline. This name change would more accurately describe our subject to those who have an old image of what we do based on the word graphics. The new name would be based on modeling and modified using the words geometric and engineering. *Engineering geometric modeling is the process used to ideate, refine, and document the engineering design and production process.*

The Engineering Geometric Modeling Paradigm

The engineering geometric modeling paradigm is based on three frames of references:

1. Visual science is the source of subject matter for engineering geometric modeling.
2. Engineering geometric modeling is a visual science applied to the design and production processes.
3. Engineering geometric modeling must reach beyond traditional boundaries and be based on 3D geometric modeling.

Therefore it is suggested that the new paradigm for engineering geometric modeling curricula should be:

The discipline of engineering geometric modeling is a visual science based on 3D geometric modeling applied to engineering design and production for the purpose of preparing engineers to ideate, refine, document, produce, and service products and structures.

The Engineering Geometric Modeling Curriculum Model

Figure 5 is the engineering geometric modeling curriculum model. The upper half of the model consists of the subject matter for engineering graphics. This subject matter is the common body of knowledge that all engineering geometric modeling curricula share. The model is based on Tyler's model for developing curriculum which consists of the needs of the learner, needs of the subject, and needs of society. The needs of the learner for technical graphics is visualization. The needs of the subject would consist of graphics, and the needs of society would be engineering design and production. The bottom half of the model refers to the application of the subject matter to the engineering design and production process. The application of engineering geometric modeling to engineering design and production results in sketches, computer models used for design, simulation, and analysis, and drawings used for documentation and communication. The engineering geometric models are also useful for marketing the product or structure.

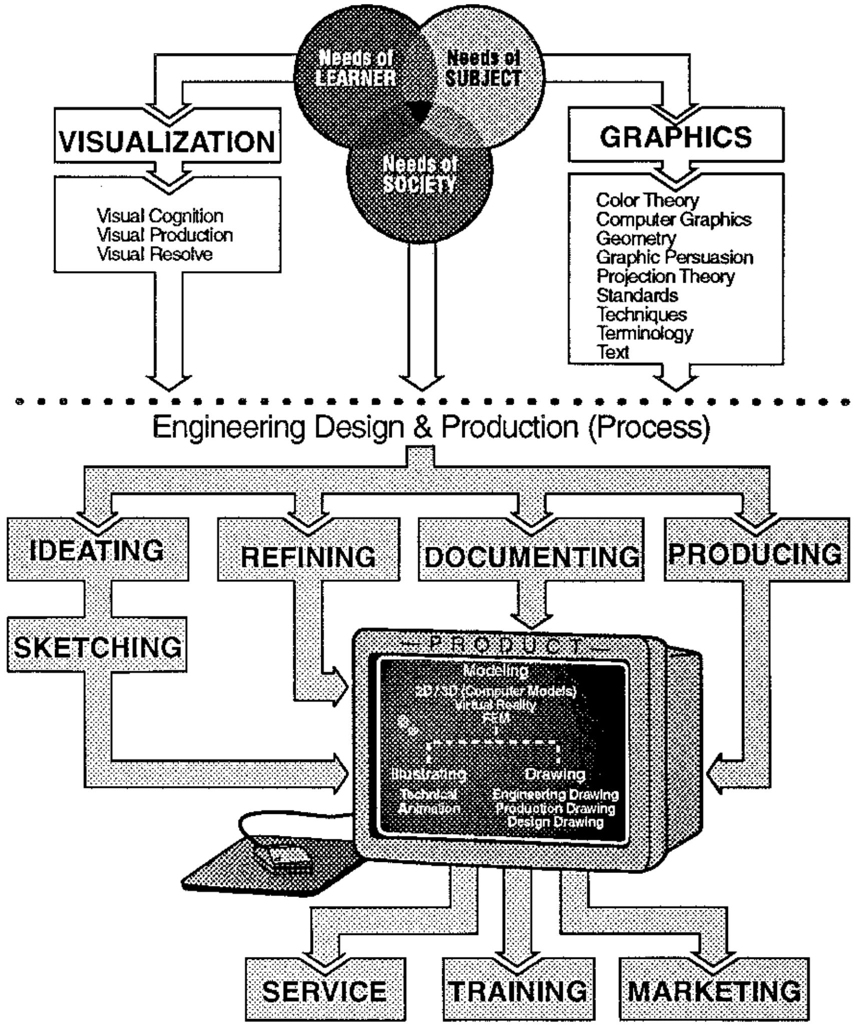

Figure 5. Engineering Geometric Modeling Curriculum Model

Visualization

Visualization is the process of mentally comprehending visual information. Visualization is the entire visual-mental process which includes perception and memory and continues to operate throughout the primary stages of visual production and visual resolve. All stages are hierarchical, are in continuous operation during the stages, and are influenced by competency levels within them (Wiley, 1989).

The visualization of graphics is based on three cognitive processes: visual cognition, visual production, and visual resolve. **Visual cognition** is the ability to mentally comprehend, store, retrieve, create, and edit visual information. **Visual production** is creating, editing, communicating, and comprehending visual products. **Visual resolve** is comprehending the termination of a design process.

An individual's visual literacy at any level has a compounding effect which directly influences competency at higher levels. So visualization should be a continuous goal of formal graphics education throughout all stages of visual learning. Just as language can be broken into various aspects such as grammar and semantics, and mathematics into algebra and calculus, the visual language must be broken into discrete elements which can be learned and manipulated to bring about desired results. Modern tools and techniques make it more important for those in engineering graphics to study the principles of visual communications, such as line, shape, color, value, contrast, repetition, etc., that are common to other visual fields. Of course engineering geometric modeling must work with visual environments and processes that demand a more technical kind of visual literacy.

Visualization should be an integral part of engineering geometric modeling. It is an on-going process that should be integrated throughout the curriculum. Visualization should also be taught as a discrete unit of study early in the curriculum using techniques common to other visual disciplines, and using results of visualization research but with a technical inclination. Various traditional and non-traditional techniques can be employed to integrate visualization into the curriculum (Miller, Bertoline, & Wiley, 1990).

Geometry

For the instructor of engineering geometric modeling, the geometry or graphics part of visual science is the most important component of the body of knowledge and the one traditionally emphasized in the curriculum. All types of drawings or graphics depend on an underlying subject matter. This underlying subject matter contains elements that are unique to the field of visual science as well as elements from other fields, such as mathematics, and science.

Geometry is a branch of mathematics that deals with properties, relationships, and measurements of points, lines, angles, planes, and solids. Geometry is a major component of graphic science that underlies engineering geometric modeling.

When studying geometry it can be from a mathematical perspective or from the visual perception perspective. The mathematical perspective will not only describe geometry in a visual sense but would also include the mathematical basis. A cylinder can be described in terms of what it looks like (two circular ends and two limiting elements) and it can be mathematically represented using an algebraic equation.

Geometry includes:

Plane Geometry
The geometry of planar figures, models and their relationships.

Solid Geometry
The geometry of 3 dimensional figures, models and surfaces and their relationships.

Analytic Geometry
The analysis of geometric structures and properties principally using algebraic operations and position coordinates.

Descriptive Geometry
The graphic representation of plane, solid, and analytic geometry used to describe real or imagined technical devices and objects. Descriptive geometry includes projection theory, terminology, and the techniques that have developed over the years to represent real or imagined objects. Descriptive geometry is used as Gaspard Monge used the term 200 years ago in the preface of his book *Geometrie Descript*: The representation of three-dimensional objects on two-dimensional paper. (Monge, 1795). Even computers display graphics on a two-dimensional device. So the use of the term descriptive geometry still applies today.

One other important area of geometry would be geometric conditions. A geometric condition is the special environment that can occur between 2- and 3-dimensional geometry. Tangencies, parallelism, and perpendicularity are some common examples of geometric conditions.

Projection theory are the set of principles which govern the graphical representation of 3D concepts, objects, structures, and environments onto planes of projection. Projection theory would explain perspective and parallel projection techniques using various methods, such as the glass box or direct view.

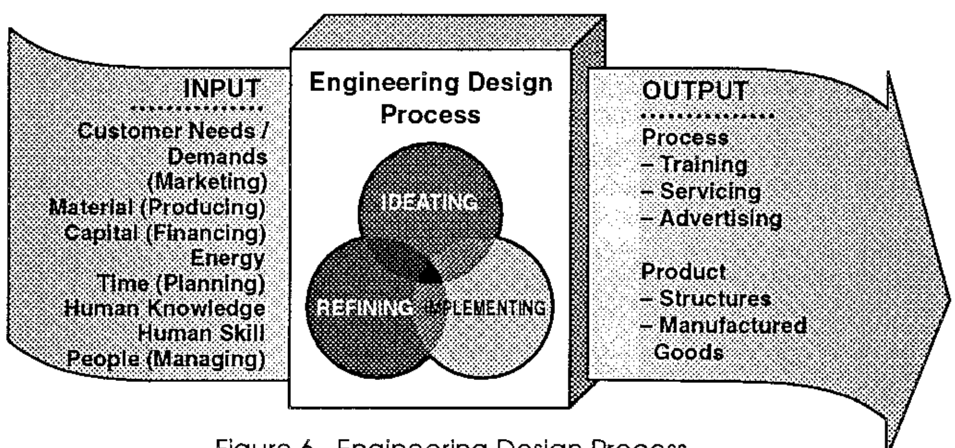

Figure 6. Engineering Design Process

An important component of projection theory is viewing conditions. Viewing conditions are the principles that govern how geometry appears when observed under different situations. Examples of viewing conditions are parallel, perpendicular, and inclined.

Other geometry subject matter consists of color theory, text, computer graphics, standards, and techniques. All of the areas under geometry in Figure 5 should be part of the core courses in an engineering geometric modeling curriculum. However, some areas would have much more emphasis or would be emphasized later in the curriculum when they could be applied.

Engineering Design *AND* Production

Engineering design and production is a process that uses graphics as its primary medium for communications. The bottom half of Figure 5 represents the engineering design graphics curriculum model based on concurrent engineering methodologies. The engineering design process can be divided into three stages (Bertoline, et al.; McKim; Juricic & Barr, and Rodriguez). McKim uses ideation, communications and documentation as his three stages. Initially, Juricic and Barr used three stages but have since changed it to four: ideation, development, communication, documentation. Rodriguez uses three phases: ideation, simulation, and implementation. The work of Bertoline, et al., chose three stages but rejected the use of the term communications because it was felt that it was too broad a term with many connotations. Language, speaking, and writing are all forms of communication but those areas are not what graphicians are concerned with in the engineering design process. The term **refinement** was chosen to replace communication because it better describes what the engineer is trying to accomplish at this stage in the design process using graphics.

Design engineers are concerned with the creation of drawings or computer models to ideate, refine, and implement technical ideas. (See Figure 6). The graphics or computer geometric data base which is produced is a by-product of engineering design.

Ideation is a mental process used to develop ideas. (See Figure 7). In simple terms it is the act of thinking. However, ideation is a very structured approach to thinking for the purpose of solving a problem. Ideation is the conceptual phase of the design process because the basic design is conceived during ideation. The ideation phase will produce many rough sketches and conceptual computer models called ideation drawings. Ideation drawings are used to communicate to oneself and others when exploring new ideas through the use of rough sketches and computer models. Engineers and other project team members will communicate more effectively if they have engineering modeling skills and knowledge.

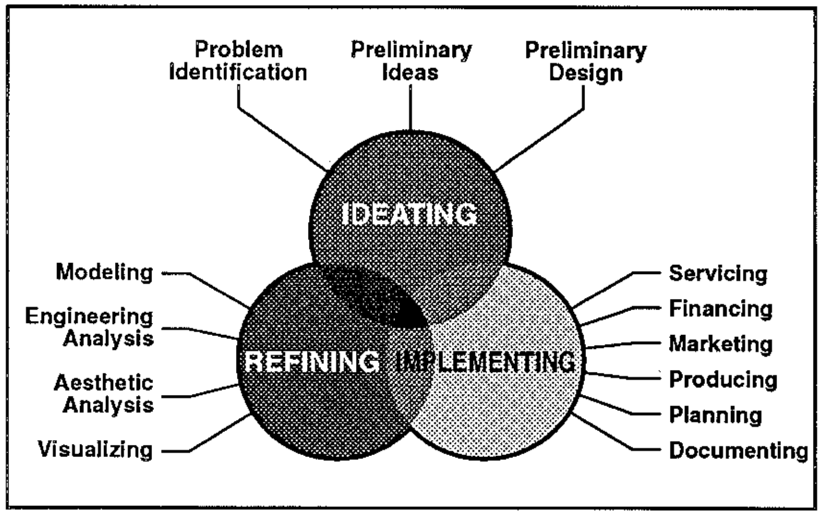

Figure 7. Concurrent Engineering Design Model

Figure 5 shows sketches outside of the computer terminal which represents the computer geometric data base. However, there are some parametric design CAD systems that can be used to sketch ideas which are then turned into more formal or refined models. For this reason and the observation that sketching will be an important part of the engineering design process for many more years, sketching may become an integral part of computer modeling.

Refinement is an iterative process used to test the preliminary design and make changes, determine if it meets the goals of the project, then decide on the final design. (See Figure 7). The preliminary idea is tested physically using finite element analysis, kinematic tests, animation, interference checking, and others. This stage is heavily dependent on geometric models to document, visualize, and communicate the design idea.

Implementing is the process used to change the final design from an idea into a product, process, or structure. The implementation process will include nearly every phase of the business, such as manufacturing, marketing, documentation, and servicing. The goal of this phase is to make the design solution a reality for the industry and the consumer.

Technical **document drawings** are used to formally record the implementation process of engineering design using accepted standards. This type of drawing is the most formal and standardized. The primary purpose of document drawings is for the communication of design information between humans, and humans and machines, for the production, planning, documenting, marketing, financing, and servicing of the product or structure. See Figure 7.

Occasionally **production drawings** are created for the primary purpose of communicating the production process. Engineering design and production are concurrent processes (concurrent engineering) in modern industry. The design *process* is not radically altered when production is integrated. Concurrent engineering includes the needs of the production process within the design of the product. So production people are involved in the design process from the start. Sketches, models, and drawings are the communications *products* that are generated as a result of the design, production, and other processes.

Computer Modeling for Engineering Design *AND* Production

The production of a 3D computer model represents a very significant feature in a modern engineering curriculum. By producing a 3D computer model, the data base can be shared with the whole organization. No longer is it necessary to create production drawings from scratch. Orthographic views can be created from the 3D data base. The 3D model can be used as the base geometry for technical illustrations and animations. This sharing of data becomes the backbone for a modern engineering geometric modeling curriculum. The data does not have to be limited to 3D models but can include all kinds of design data, such as text and numeric information displayed graphically.

Sketches are most likely to occur in the ideation phase of the design and production process, although sketches are used throughout. These sketches serve as inputs into the modeling of the design. The refinement process will use real or computer models to assist in the refinement process. Computer models can be used for interference checking, finite element analysis, production process analysis, and kinematics. Future techniques may include virtual reality modeling. The final models are used to create document drawings, such as engineering drawings for communications within the company, production drawings, and NC programs.

The models can also be used as the graphical input for simulation. The simulation process is applied to Finite Element Analysis (FEA), kinematic studies, and other analysis tasks that require a dynamic graphical display. The marketing *process* uses illustrations derived from the 3D model for technical publications such as sales and advertising brochures and animations for advertising. The service and training process uses illustrations and animations for service and training.

Engineering Modeling Course Outline

A proposed engineering modeling course has been developed and is shown in Attachment 1 at the end of this paper. The engineering modeling course outline would have both traditional and modern components. The traditional units of study would focus on sketching practices as applied to ideation. The course content is derived from the engineering geometric modeling curriculum model and includes: visualization, geometry, modeling, simulating, and implementing. Modern units of study would include modeling theory and techniques, Boolean logic, transforming 3D models into 2D drawings, spatial analysis using computer models, and application problems.

This course would focus on the development of sketching and CADD modeling abilities in the development of visualization skills, engineering graphics standards, and three-dimensional modeling for the design, analysis, and documentation of the engineering design and production process.

Implementing the Model

The curriculum model can be used as a guide to modernize the curriculum within the framework of present courses. The proposed implementation suggests that visualization and modeling are the core areas and must be taught in the freshman year. The discipline is at a very important crossroads in its continued development and it is time to seriously look at what we are doing and why it is being done. There is a need for a basic philosophical change based on a new paradigm. This new paradigm is not based on drafting but on geometric modeling. Change may be difficult, but what is the alternative?

When confronted with major change, individuals and organizations react by denying that a problem exists. Denial may last a short time or it may never end. Until the individual or organization admits that change is necessary the problem will remain and no significant changes can occur. We must face up to the fact that we are not serving the needs of engineers by teaching drafting. In *Alice's Adventure in Wonderland,* by Lewis Carroll, 1865, the Cheshire Cat gave this advice:

"Chesire Puss," Alice began, rather timidly... "Would you tell me please, which way ought I go from here?"

"That depends a good deal on where you want to get to," said the Cat.

"I don't care where-" said Alice.

"Then it doesn't matter which way you go," said the Cat.

"-so long as I get somewhere," Alice added as an explanation.

"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

If you do not care where you are going then it really does not matter if engineering graphics stays on its present course. However, if you do care then it matters very much which path you take. The discipline needs a vision which will shape the future and transform us so that as a group we can lead our students and our discipline into the 21st century.

Selected References

Barr, L. S. (1988). Fundamentals of CADD-based engineering graphics. 1988 *ASEE Annual Conference Proceedings*, 952-956.

Barr, R. E. & Juricic, D. (1991). A new look at the engineering design graphics process based on geometric modeling. *Proceedings of the 1991 Engineering Design Graphics Mid-Year Meeting,* Tempe, Arizona. 129-136.

Barr, R. E. & Juricic, D. (1990, August). The engineering design graphics curriculum modernization project. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum.* Austin, Texas. 23-42.

Bertoline, G. R., Bowers, D., McGrath, M. B., Pleck, M. H., & Sadowski, M. (1990, November). A conceptual model for an engineering graphics curriculum for the year 2000. *Proceedings of the 1990 Mid-Year Meeting of the Engineering Design Graphics Division of ASEE,* Tempe, AZ, 241-254.

Bertoline, G. R. (1991). Using 3D geometric models to teach spatial geometry concepts. *The Engineering Design Graphics Journal*, 55, (1), 37-47.

Bertoline, G. R. (1988). The implications of cognitive neuroscience research on spatial abilities and graphics instruction. *Proceedings of the Third International Conference on Engineering Graphics and Descriptive Geometry,* Vienna, 1, 28-34.

Bertoline, G. R. (1988). The role of computers in the design process. *The Engineering Design Graphics Journal,* 52, (2), 18-22.

Bertoline, G.R. (1987). Future directions for engineering design graphics. 1987 *Frontiers in Education Conference Proceedings,* Terre Haute, IN. 625-630.

Bertoline, G. R., & Pleck, M. H. (1990, August). A knowledge-based curriculum for engineering design graphics. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum.* Austin, Texas, 75-84.

Booker, P. (1962). *The history of engineering drawing*. London: Chatto & Windus.

Bowers, D. H., Wagner, N. P. and Beakley, G. C. (1987, Winter). Student attitude toward drawing for engineers. *The Engineering Design Graphics Journal*, 51, (1), 30-37.

Bowers, D. H., Evans, D. L. and Beakley, G. C. (1986). The role of CAD in a freshman engineering program. *1986 ASME International Computers in Engineering Conference*, Chicago, IL, 119-124.

Bowers, D. H., & Evans, D. L. (1990, August). The role of visualization in engineering design. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum*. Austin, TX, 89-94.

Carlson, D. A. (1990, August). Contemporary approaches to the fundamentals of engineering design graphics - building an integrated four-year curriculum path. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum*. Austin, TX, 153-160.

Duff, J. M., (1987). Trends in engineering graphics education. *1987 Frontiers in education conference proceedings.* Terre Haute, IN. 620-623.

Duff, J. M. (1990, August). The curriculum modernization project without a curriculum. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum. Austin*, TX, 85-88.

Evans, D. L., Bowers, D. H., & Beakley, G. C. (1986). Microcomputer application software and freshman engineering. *Proceedings of the 1986 ASME International Computers in Engineering Conference.*

Giffi, C., Roth, A. V., & Seal, G. M. (1990). Competing in World-class *Manufacturing: America's 21st century challenge.* Homewood, IL: Business One Irwin.

Makino, K., Saito, T., Shiina, K., Suzuki, K., and Jingu, T. (1992). Analysis of problem solving process of a mental cutting test by the use of eye fixations data. In V. O. Thomas & W. P. Lewis (Eds.), *Proceedings of the 5th International Conference on Engineering Computer Graphics and Descriptive Geometry.* Melbourne, Australia, 2, 398-402.

McKim, R. H. (1980). *Experiences in visual thinking*, (2nd Ed.). Brooks/Cole Publishing.

Miller, C. L. (1992). The results of integrating real and computer generated models into a traditional sketching based engineering graphics course. *The Engineering Design Graphics Journal*, 56, (1), 27-47.

Miller, C. L., & Bertoline, G. R. (1991). Spatial visualization research and theories: Their importance in the development of an engineering and technical graphics curriculum model. *The Engineering Design Graphics Journal*, 55, (3), 5-14.

Miller, C. L., Wiley, S. E., & Bertoline, G. R. (1990). Strategies for improving the visualization ability of engineering graphics students. In O. Ural & L. D. Shen, (Eds.). *Proceedings of the 4th International Conference on Engineering Computer Graphics & Descriptive Geometry,* Miami, FL.

Monge, G. (1795). *Geoemtrie Descript.* Paris, ANVII.

A national action agenda for engineering education. (1987). *A report of the Task Force on a National Action Agenda for Engineering Education*, ASEE, Washington, DC.

Pleck, M. H., McGrath, M. B., Bertoline, G. R., Bowers, D. H., & Sadowski, M. A. (1990, August). Factors affecting the engineering design graphics curriculum: Past, Present, and Future. *Proceedings of the NSF Symposium on Modernization of the Engineering Design Graphics Curriculum.* Austin, TX.

Rodriguez, W. (1992). *The modeling of design ideas.* New York: McGraw-Hill.

Ross, W. L., & Ross, W. A. (1992). Early influences of the U. S. military academy on engineering and engineering graphics education in the United States. *The Engineering Design Graphics Journal*, 56, (1), 22-26.

Sadowski, M. A. (1990). The ACM-SIGGRAPH delphi: A report to the engineering design graphics membership. *Proceedings of the 1990 Engineering Design Graphics Mid-Year Meeting*, Tempe, Arizona.

Savage, E., & Sterry, L. (1990). *A conceptual framework for technology education.* Reston, VA; International Technology Education Association.

Schubert, W. H. (1986). *Curriculum: Perspective, Paradigm, and Possibility.* New York: Macmillan Publishing Company.

Tyler, R. W. (1950). *Basic principles of curriculum and instruction.* Chicago: University of Chicago Press.

Ullman, D. G., Wood, S., & Craig, D. (1989, Fall). The importance of drawing in the design process. *Design in Engineering Education Division Bulletin*, 14, (1), 6-12.

Wiley, S. E. (1990). Computer graphics and the development of visual perception in engineering graphics curricula. *The Engineering Design Graphics Journal*, 54, (2), 39-43.

Wright, R. T. (1992). Implications of a conceptual framework for technology education (Jackson's Mill II). *Journal of Epsilon Pi Tau* 53-58.

ATTACHMENT 1

Outline for the proposed Engineering Modeling Course
by:
Craig L. Miller & Gary R. Bertoline

Lecture	Laboratory
1. Introduction/visualization	Visualization problems
Visualization problems	
Need for Graphics	
Why use Graphics?	
The Design Process	
Ideation	
Refinement	
Documentation	
Course Content	
Graphics theory	
Plane & Solid Geometry	
Standards	
Conventions	
Visualization	
Modern Tools	
Sketching	
Visualization in Engineering Design	

Faculty Training in Computer Graphics and Analysis for Undergraduate Engineering Design Education

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Abstract

Two workshops on computer graphics, geometric modeling and finite element analysis, sponsored by Clemson University and the National Science Foundation, were held on the Clemson campus during the summers of 1990 and 1991. The purpose was to further educate engineering faculty who teach undergraduate courses in the cited areas on new methodologies needed for computer-aided design. A total of 45 faculty members from a widely distributed national sample participated in these programs. The implementation details, workshop contents, and various ways in which participants benefited are described.

Funds for this project were obtained through the National Science Foundation, Grants USE-8950070 and USE-9054256.

Rationale

There is no doubt that digital computers have had a major impact in the engineering design process. Computer-aided methodologies, especially computer-aided design and computer-aided manufacturing (CAD/CAM) technologies, have changed the way engineering is currently perceived and conducted. In order to adjust to these changes, universities throughout the country, and more specifically colleges of engineering, have had to comply with the need to modify engineering curricula and shape new programs.

It has been said that the essence of engineering is design [Richards & Jacobson, 1988]. In the mechanical and industrial fields, the word "design" represents more than just the description of geometric components – it includes analysis, evaluation, and synthesis. The schematic in Figure 1 shows a typical design cycle [Sadegh, 1988].

The incorporation of computer graphics, geometric modeling and finite element analysis, reflecting the design cycle described above, is particularly important in the undergraduate engineering curriculum [Newton, 1991]. Until now the computer has primarily been utilized for data storage and numerical processing, producing voluminous quantities of numerical results. Computer graphics and geometric modeling, combined with computer analysis, are the elements that transform these difficult to interpret numerical solutions into the visual interpretations needed for engineering design. They enhance the students' ability to understand the design process. They also bring engineering design education into a better perspective by allowing students to gain a certain amount of "real-world" experience through meaningful computer exercises.

The importance of design in engineering education has been particularly stressed by the Accreditation Board for Engineering and Technology (ABET) during its accreditation process of undergraduate engineering programs. Computer-aided modeling and analysis, integral parts of computer-aided design, should, therefore, be focused at the very core of undergraduate engineering education. Engineering schools can no longer ignore these technologies but must move to integrate them within the conceptual aspects of engineering design.

Before computer-aided modeling and analysis can be used to enhance the content of undergraduate design courses in various engineering disciplines, the faculty responsible for these courses must thoroughly understand these new tools. Computer graphics, geometric modeling and finite element analysis are just beginning to be implemented in the engineering undergraduate curriculum.

Engineering faculty teaching design courses must become familiar with these subjects if they are to keep their students informed about the latest engineering processes used in industry. In order to fulfill this goal, two NSF-funded workshops were offered on the Clemson campus. Participating faculty were introduced to computer graphics, geometric modeling, finite element analysis, and their role in the undergraduate engineering design curriculum.

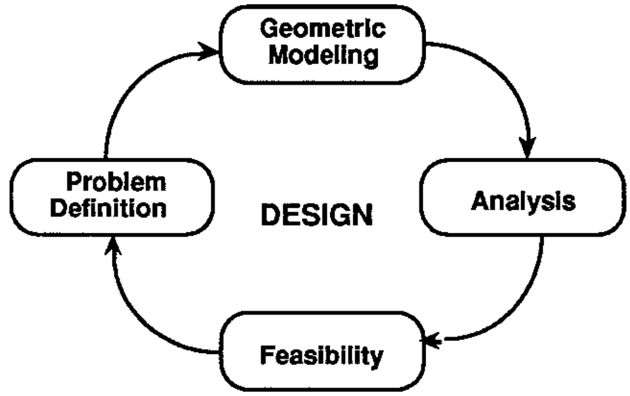


Figure 1. A typical design cycle

Workshops Objectives and Implementation

The main objective of the two workshops was to give participating faculty the ability to answer the following questions:

1. What are the general concepts of computer graphics, geometric modeling and computer analysis?
2. Why is it important to use these topics in undergraduate engineering design courses?
3. How can they be successfully integrated into the undergraduate design curriculum?

This major objective was accomplished by addressing three different areas during the execution of the workshop programs:

1. Introducing the participating engineering faculty to the basic theoretical concepts of computer graphics, geometric modeling and computer analysis which bear on their teaching of undergraduate design.
2. Allowing the participants to obtain first-hand experience with state-of-the-art computer graphics and finite element systems, demonstrating ways in which these systems can be integrated into an existing undergraduate design curriculum.

3. Reviewing and discussing curricular issues relating to the introduction of these high technologies into undergraduate engineering design courses.

To fulfill the objective listed above, two one-week workshops supported by the National Science Foundation were conducted during the summers of 1990 and 1991. These workshops focused on the need to revise the undergraduate engineering design curriculum in various engineering disciplines, with a view toward more emphasis on the use of computer graphics, geometric modeling and computer analysis.

TABLE I SCHEDULE OF ACTIVITIES Workshop I		
DAY	**SESSION**	**TOPICS**
1	Morning *lecture*	Graphics System for CAD, Graphics Software
	Afternoon *laboratory*	Intro to Computer Graphics Library
2	Morning *lecture*	Data Structures for Computer Graphics. 3D Model Representation - Intro to Solid Modeling
	Afternoon *laboratory*	Solid Modeling Systems - Model Creation
3	Morning *lecture*	Realism in 3D Graphics Role of Solid Modeling in the Design/ Analysis/Manufacturing Process
	Afternoon *laboratory*	Application of Computer Graphics techniques to the solution of engineering design problems
4	Morning *lecture & lab*	Computer Graphics integration into a standard undergraduate engineering curriculum - SESSION 1
	Afternoon *lecture & lab*	Continued - SESSION II
5	Morning *lecture & lab*	Continued - SESSION III
	Afternoon	Discussion of participants proposals for integration of computer graphics in specific design courses.

Table I. Schedule of Activities for Workshop I

The contents of the workshops were divided as follows:

Workshop I

Computer graphics topics for undergraduate engineering design, including: graphics hardware and software, 2D and 3D transformations, viewing operations, graphics modeling and data structures.

Workshop II

Geometric modeling and computer analysis for undergraduate engineering design, including: parametric curve and surface representations, solid modeling principles and finite element analysis. In both workshops, the introduction to high-technology topics in computer graphics, geometric modeling and finite element analysis was followed by an intense study of applications of these topics to undergraduate engineering design courses. Informal discussion sessions were held at the end of each day, aimed at sharing each individual's prior experiences with all others. Both workshops were conducted in a similar format, with lectures in the mornings and experiential laboratory sessions in the afternoon. (Tables I and II give the schedule and content of each workshop).

Tutorials on the use of the computer systems with introductions to the various software packages presented during the week were distributed at the start of each laboratory session and are described below. The computer laboratories were also available to the workshop participants from 8-11 p.m., and were well utilized during these evening hours. Graduate assistants provided additional help during all laboratory sessions, creating a more individualized learning environment. The hardware and software used in these workshops is described in Table III. The allocation of one participant per workstation was found to be ideal, in view of the wide variety of participants' backgrounds and experiences.

Laboratory Materials

Several self-paced instructional packages were developed for use during the laboratory sessions, including various exercises to be solved by the workshop participants. The following is a description of this instructional material:

1. Introduction to the SUN Sparc 1 workstation, the UNIX operating system, and the VI editor.
2. Introduction to a computer graphics library, enabling the participants to modify graphics programs written in FORTRAN and understand the concepts of windows, viewports, and clipping.
3. Use of the graphics library to modify computer graphics code needed to transform (translate, rotate and scale) geometric objects.
4. Editing of a menu-driven program used for the transformation of 3D objects. This tutorial also provided information on the creation of geometric databases.
5. Development of various solid models using a commercial solid modeler. The principles of Analytic Solid Modeling (ASM) were discussed in this tutorial.
6. Creation of various solid models by Constructive Solid Geometry (CSG) with primitive instancing and boolean operations.
7. Design and analysis of mechanisms using a computer program for the dynamic and kinematic analysis of machines. These tutorials were structured to give the participants an opportunity to use computer graphics in mechanism design.
8. Finite Element analysis applications, using a commercial finite element program. Various engineering problems were analyzed, including a rectangular plate with a hole subjected to various loading conditions.

TABLE II
SCHEDULE OF ACTIVITIES
Workshop II

DAY	SESSION	TOPICS
1	Morning *lecture*	Data structures for 3D modeling Solid modeling concepts
	Afternoon *laboratory*	Introduction to solid modeling systems
2	Morning *lecture*	Role of solid modeling in the Design/ Analysis/Manufacturing process
	Afternoon *laboratory*	Applications of solid modeling to the solution of engineering design problems
3	Morning *lecture*	The Finite Element Method - basic concepts
	Afternoon *laboratory*	Introduction to Finite Element Software - engineering applications
4	Morning *lecture*	Solid Modeling/Finite Element Analysis - Integration into a Standard Undergraduate Engineering Curriculum SESSION I
	Afternoon *lecture & lab*	Continued - SESSION II
5	Morning *lecture & lab*	Continued - SESSION III
	Afternoon	Discussion of participants' proposals for integration of solid modeling and finite element analysis in specific design courses

Table II. Schedule of Activities for Workshop II

TABLE III FACILITIES AVAILABLE FOR THE WORKSHOPS	
Computer Modeling Lab I:	
20	SUN Sparc 1 workstations
2	HP Laser printers
1	SUN 4/470 File Server System, with 3 gigabytes of disk space
	All networked through ETHERNET, TCP/IP
Computer Modeling Lab II:	
20	SUN Sparc 1+ workstations
1	HP laser printer
1	HP drum plotter
2	SUN 4/280 File Server Systems, with 3 gigabytes of disk space each
4	SPARC 2 File Server Systems, with 1 gigabyte of disk space each
Software Available:	
PATRAN, ANSYS, IDEAS, HOOPS, ABAQUS,MATHEMATICA	

Table III. Facilities available for the workshops

Faculty Participants

The workshops were designed for faculty members engaged in undergraduate engineering design instruction. To be selected for participation in a workshop, a faculty member was expected to teach undergraduate design courses, know basics of FORTRAN programming, and have a general knowledge of computers. Brochures announcing each workshop were sent to engineering schools nationwide.

Applicants were asked to submit their curriculum vitae and a narrative stating the following:

1. Future plans: what, specifically, did applicants plan to do with the new knowledge received at the workshop, and the relationship of those plans to the current program in their discipline.
2. Current computer graphics, modeling and analysis resources: what was available at the applicant's institution, including equipment and software.
3. Undergraduate design courses: design courses taught to undergraduate students which could benefit from the use of computer graphics, geometric modeling and finite element analysis.
4. Experience: what experience the applicant would bring to the planned development, including, for example, computer experience or design expertise.

The applicants were also asked to submit supporting information from their department heads to verify that the proposed plans were supported by the department, including commitments toward the improvement of undergraduate design courses. The selection of participants was based on the following criteria:

1. the quality and appropriateness of the planned development,
2. the preparation of the applicant to do the planned development, and
3. the support shown by the home institution.

Nearly 150 applications were received for the 25 slots in Workshop I and 20 slots in Workshop II. The breakdown of applicants by various states is given in Table IV. The selection process took into account NSF's requirement that special consideration be given to underrepresented groups in engineering – women (6 participants) and minorities (6 participants).

Impact of the Programs

On the last day of each workshop the participants were asked to fill out an evaluation form. The comments were very positive both on content and on format. The participants were also divided into small groups (4 to 5 in each group) to discuss specific questions related to the use of computer graphics, geometric modeling and finite element analysis in the undergraduate engineering curriculum. The following is a summary of these "brain-storming" sessions:

1. It was felt that all engineering students should be exposed to the basics of computer graphics, geometric modeling and finite element analysis.
2. Computer graphics/geometric modeling should be used for 3D visualization as a "black-box", without exposure to the underlying theory, in the freshman/sophomore year.
3. A more comprehensive elective course should be offered at the junior/senior level, in preparation for capstone design courses.
4. Engineering students should be exposed to the finite element method early in the undergraduate curriculum, integrated into existing courses, such as Strength of Materials.
5. An in-depth course on finite elements should be offered at the senior level to tie with the capstone design courses.

There seemed to be agreement among participants that students do not have to be "trained" to use specific software packages popular in the industrial environment. However, continuity of usage of a specific software during the four undergraduate years would be preferable. The participants stated that engineering schools should recognize the fact that faculty must be given time to gain and maintain proficiency in these areas. It was also recognized that the mechanisms for appropriate faculty training would vary from institution to institution. As a result of attending Workshops I and II, eight new courses were developed by participants at their institutions, and sixteen changes in existing course descriptions were reported.

TABLE IV

PARTICIPANTS' GEOGRAPHIC DISTRIBUTION

Workshop I:		Workshop II:	
State	*Number of Participants*	*State*	*Number of Participants*
Alabama	2	California	1
Connecticut	2	Idaho	1
Florida	3	Indiana	3
Illinois	1	Lousiana	1
Indiana	1	Massachusets	1
Kentucky	1	Missouri	1
Louisiana	2	Montana	1
Maryland	2	Ohio	1
Michigan	1	Oregon	1
Minnesota	1	Pensylvania	1
Mississippi	1	Tennessee	1
New York	1	Texas	2
Ohio	1	Washington	1
Tennessee	1	Wisconsin	1
Texas	1		
Washington	3		

Table IV. Geographic distribution of participants

Conclusions

The concept of faculty training in new technologies resulted in two very successful programs supported by the National Science Foundation. The workshops on Computer Graphics, Geometric Modeling and Finite Element Analysis held on the Clemson campus proved extremely valuable to its participants and more programs of this type should be implemented. The need to incorporate these technologies into the undergraduate curriculum of various engineering disciplines was established and the new technology is presently being implemented in many of the institutions represented in the above cited programs.

References

Newton, A. (Chair), (1991, July). Integrating Computer Graphics in Design Education. *Computer Graphics*, 25, (3).

Richards, L. G., & Jacobson, I. D. (1988). Compute aided engineering at the University of Virginia: 1988. *Proceedings of UPCAEDM*, pp. 236-240.

Sadegh, A. M. (1988). A Computer Aided Design and Analysis Program. *Proceedings of UPCAEDM*, pp. 245-247.

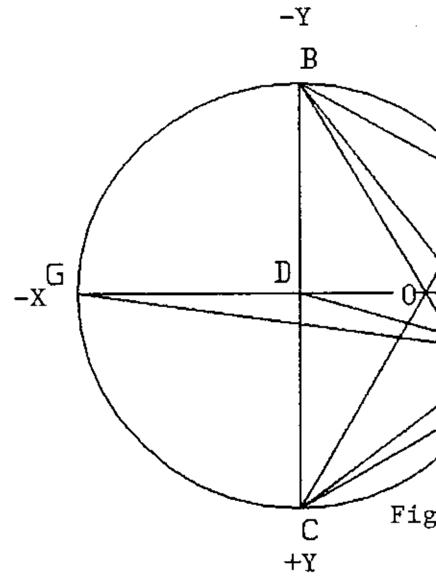
After establishing the fact that angle MNK of Fig. 1. is three times the magnitude of angle MCK: further investigations were undertaken to determine the x, y coordinates of the designated points shown in that diagram, with respect to the origin, O, the point of intersection of the medians of the equilateral triangle. The orientation of the x, y axes is shown in Fig. 2.

From among the first observations of the entire graphical system was the realization that the right triangle at K was common to all three triangles, i.e., MKN, MKC, and BKC. Therefore, the incenter of each triangle lies on the bisector of this right angle. In addition, since side MN is common to triangles MKN and MKC, their circumcenters lie on a line parallel with KC drawn through the mid-points of KM, MN, and MC.

The center of the nine point circle for each of the triangles, MKN and MKC, are on a line parallel with KC situated at a distance KM/4 from line KC. The center of gravity of each of these two triangles are also on the line parallel with KC, and situated a distance KM/3 from it.

A line was drawn connecting points K and D. This established the isosceles triangle KDC where DC = DK, angle KCD = DKC, and angle KDO = (2Θ-30°).

The length of line MN is considered to be R, while the length of the sides of the equilateral triangle ABC is S. R is computed accordingly:



Fig

$R=S/(\sqrt{3}+2*COS($

The slope, m of
positive and equals t
ing:

m = SIN(30°+ Θ)/COS

or COS(60°-Θ)/SIN(6

Next, a line fr
was constructed per
to, and intersecting
P. The coordinates
shown in the Table
nates. Since line
pendicular to MN it's

m = - SIN(60°-Θ)/C

From the geomet
2 it may be proved t
This is true, even
values appearing in
of Coordinates do not
be equal.

P is also at th
tangency of line MN
EPF whose center is
and line constructed

to arc EF whose center is A, and intersecting medians CF at M and BE at N, will be the hypotenuse of a right triangle formed in the following manner: From C, construct an extended line CN, intersecting arc EHF at K. Then, a line from B to K contains **M**, and is perendicular to CK: angle CKB is an inscribed right angle subtended by the 180°arc, BGC.

Consequently, according to the proof submitted with Fig. 1., angle MNK is three times the magnitude of angle MCK.

From the following equation:

$$R=S/(\sqrt{3} + 2*COS(2\Theta-30°))$$

R is a dependent variables while S is independent and constant, for this example. The magnitude of **3Θ** , and **Θ** changes with that of R.

From the information contained in Figs. 1 and 2, the X, Y coordinate values for each labeled point were computed and are shown in the Table of Coordinates below. All values are with respect to the origin, O.

Table of Coordinates

Point	X	Y
A	$S\sqrt{3}/3$	0
B	$-S\sqrt{3}/6$	$-S/2$
C	$-S\sqrt{3}/6$	$S/2$
D	$-S\sqrt{3}/6$	0
E	$S(\sqrt{3}/6)SIN(30°)$	$-S(\sqrt{3}/6)COS(30°)$
F	$S(\sqrt{3}/6)SIN(30°)$	$S(\sqrt{3}/6)COS(30°)$
G	$-(S/2 + S\sqrt{3}/6)$	0
H	$S/2 - S\sqrt{3}/6$	0
K	$S(COS(2\Theta-30°)/2)-S\sqrt{3}/6$	$S*SIN(2\Theta-30°)/2$
M	$R(\sqrt{3}/3)*SIN(60°-2\Theta)$	$-R*SIN(60°-2\Theta)$
N	$R(\sqrt{3}/3)*SIN(2\Theta)$	$R*SIN(2\Theta)$

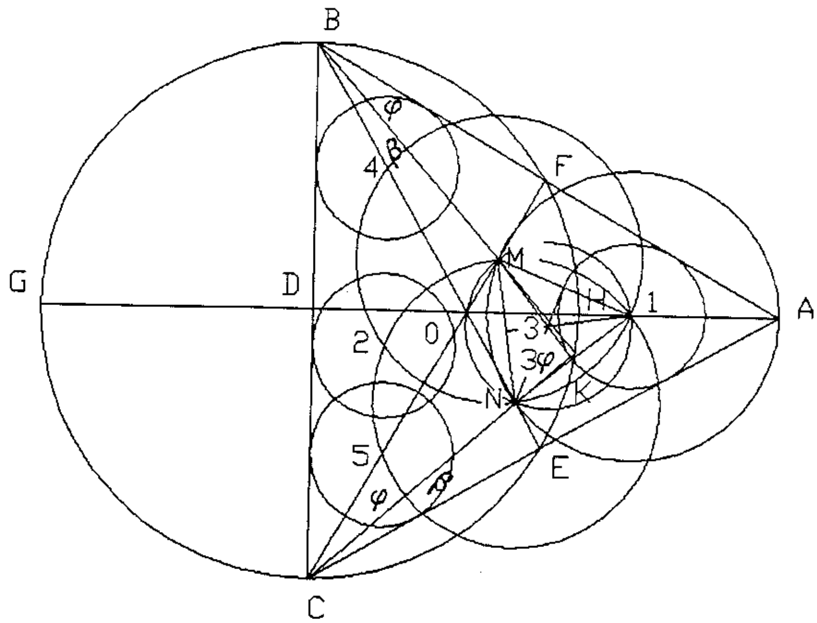
$$Px = (R*\sqrt{3}/6)*COS(2\Theta-30°) + R*SIN(2\Theta-30°)*SIN(2\Theta-30°)$$

$$Py = S*SIN(2\Theta-30°)/2, \text{ or}$$

$$Py = (R/2)*(\sqrt{3} + 2*COS(2\Theta-30°))*SIN(2\Theta-30°)$$

$$\text{Where } R = S/(\sqrt{3} + 2*COS(2\Theta-30°)), \text{ or}$$

$$R = S/(\sqrt{3} + 2*SIN(60°+2\Theta))$$



Using a copy of Fig. 1 as a starting point, two circles were initially constructed with centers at M and N with radii MN. The points of intersection of the two circles were designated as points 1 and 2, with 1 being on the x-axis. Angle 21D proved to be $(2\Theta-30^\circ)$ With point 1 as the center, another circle of the same radius was constructed. It contains points M, N, and A. Analytical analysis proved A to be in the circle. An equilateral triangle MN1 and its medians were constructed with its medians intersecting at point 3. With 3 as the center and radius 3M, a circle was drawn circumscrbing triangle MN1.

This circle also contains the origin of the coordinate system. The next step involved constructing a circle with 1 as the center, and radius M1/2, or R/2. This circle is tangent to lines AB and AC, while a circle of the same radius constructed at 2, was found to be tangent to line BC.

It should be observed that circle M with radius MN inter-sects median BE at N and point 4. Whereas circle N with the same radius intersects median CE at M and point 5. Circles at 4 and 5 with radii equal to M1/2 are also tangent to line BC. Coordinates of points 1-5 are:

Points	X	Y
1	$(2R\sqrt{3}/3)*\cos(2\Theta-30^\circ)$	0
2	$-(R\sqrt{3}/3)*\cos(2\Theta-30^\circ)$	$(R\sqrt{3})*\sin(2\Theta-30^\circ)$
3	$(R\sqrt{3}/3)*\cos(2\Theta-30^\circ)$	$(R\sqrt{3}/3)*\sin(2\Theta-30^\circ)$
4	$-(R\sqrt{3}/3)*\cos(2\Theta-30^\circ)$	$-R*\cos(2\Theta-30^\circ)$
5	$-(R\sqrt{3}/3)*\cos(2\Theta-30^\circ)$	$R*\cos(2\Theta-30^\circ)$

Letters . . .

Larry Goss received this letter from YuanFu Xu, a lecturer at Yellow River Water Conservancy Technical School, in the People's Republic of China

One Descriptive Geometry Problem

The following is a problem of intersection line of object, as is shown in Figure 1. The vertical projections and the profile projection of the object are known; the horizontal projection is demanded.

Above all, Figure 2 is observed. The intersection line of the vertical projection can easily be seen. If the horizontal cylinder is looked on as a cylinder cutting tool, which cuts the vertical cylinder, then Figure 3 is formed. Thus, we can get Figure 4, which has three answers or more. In Figure 4, the vertical projection and the horizontal projection of the object are known. The profile projection is demanded. If the cutting concept of a cylinder cutting tool arises, the similar problems such as Figure 5, Figure 6, and Figure 1, which are the so-called difficult ones, are easily solved.

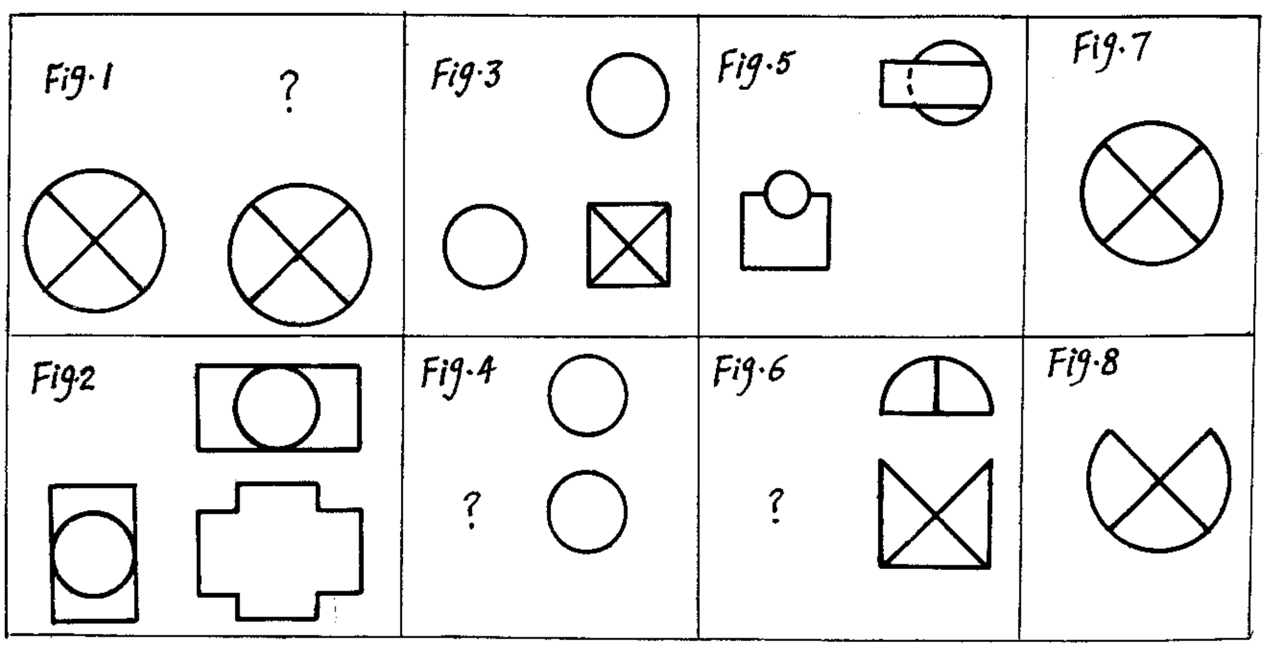
Thus, we can get Figure 7, which is the horizontal projection of Figure 1.

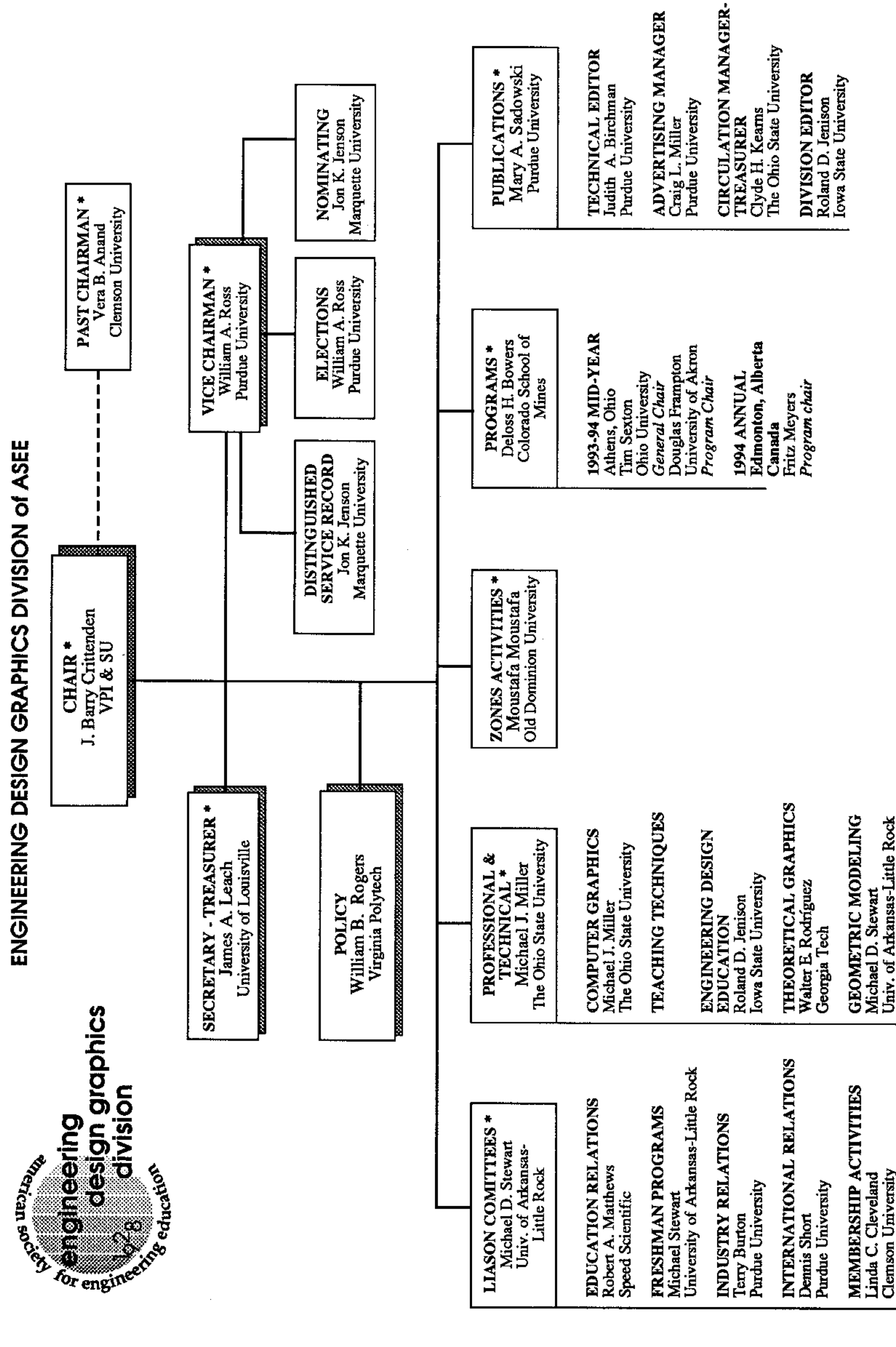
If the vertical projection in Figure 1 is changed into Figure 3, what will happen to its profile projection and horizontal projection? When the analysis is carried out according to the cutting concept of a cylinder cutting tool, the answer can easily be achieved.

Thanks to my limited knowledge, many mistakes may have been made. I hope all the the experts will give me good advice.

YuanFu Xu
Kai Feng
He Nan
People's Republic of China

徐元甫





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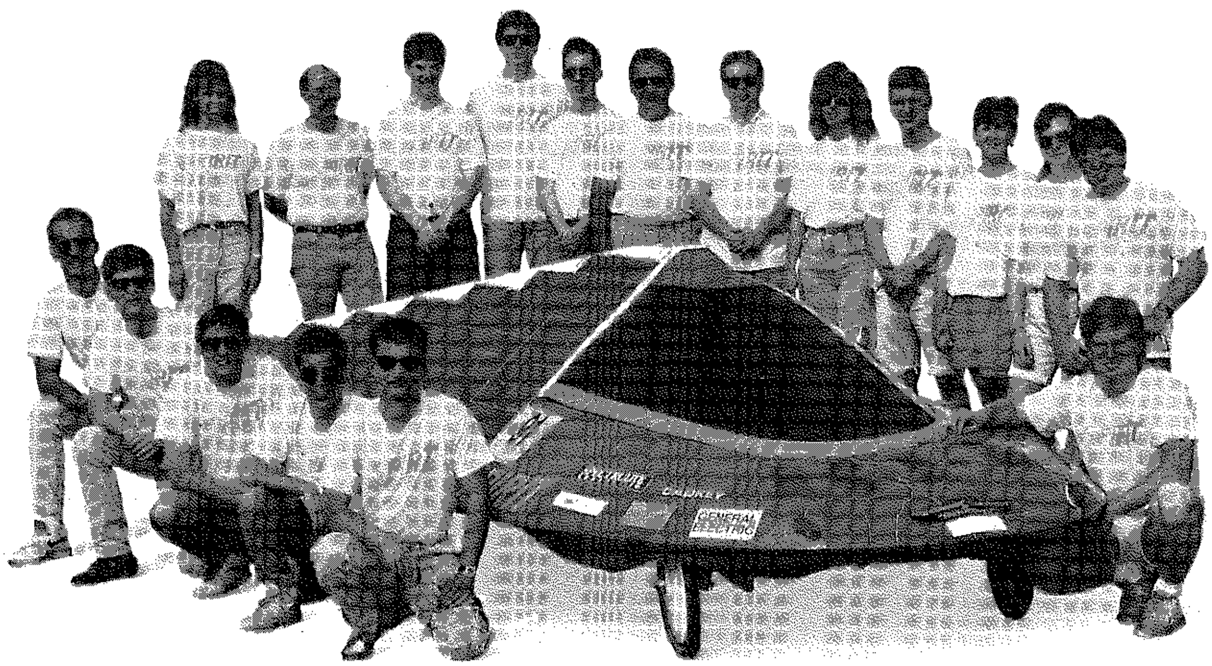

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