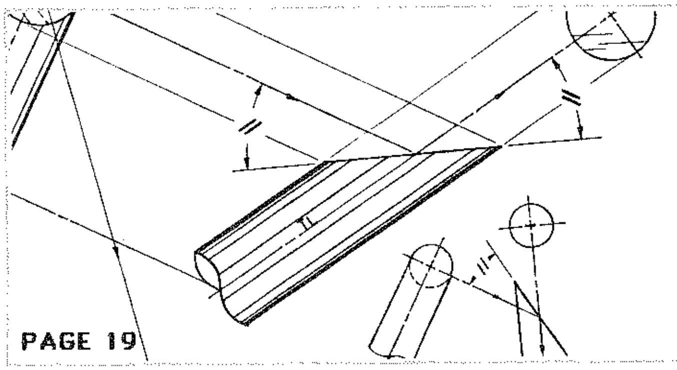

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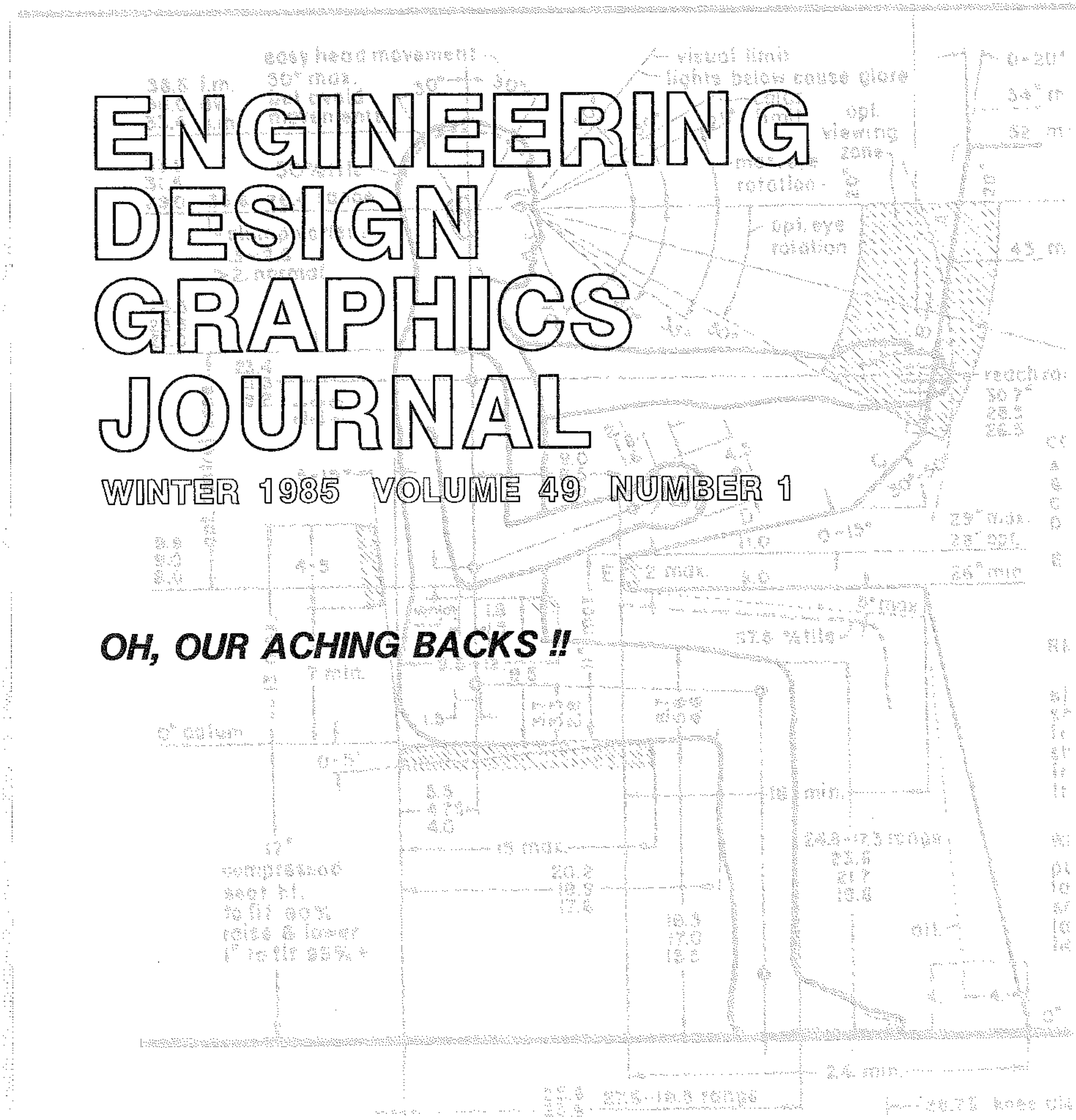
# ENGINEERING DESIGN GRAPHICS JOURNAL

WINTER 1985 VOLUME 49 NUMBER 1



***OH, OUR ACHING BACKS !!***

**CALENDAR OF EVENTS**

ASEE ANNUAL CONFERENCES
1985 ATLANTA Host: Georgia Tech
1986 CINCINNATI Host: University of Cincinnati
1987 RENO Host: University of Nevada-Reno (tent)

EDGD MID-YEAR MEETINGS
1985 WEST LAFAYETTE Host: Purdue University
1986 AUSTIN Host: University of Texas-Austin
1987 TUSCALOOSA Host: University of Alabama

**The Engineering Design Graphics Journal** is published one volume per year, three numbers per volume, in Winter, Spring, and Fall by the Engineering Design Graphics Division of The American Association for Engineering Education for teachers and industrial practitioners of Engineering, Computer, Design, and Technical Graphics.



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**ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:**

The objectives of The Journal are:

1. To publish articles of interest to teachers and practitioners of Engineering Graphics, Computer Graphics, and subjects allied to fundamentals of engineering education and graphic technology.

2. To stimulate the preparation of articles and papers on topics of interest to its membership.

3. To encourage teachers of Graphics to innovate and experiment with, and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses.

4. To encourage research, development, and refinement of theory and application of engineering graphics for understanding and practice.

**DEADLINES FOR AUTHORS AND ADVERTISERS**

The following are deadlines for submission of articles, announcements, or advertising for **The Journal**:

| | |
|---|---|
| Fall | September 15 |
| Winter | December 1 |
| Spring | February 1 |

**STYLE GUIDE FOR JOURNAL AUTHORS**

The Editor welcomes submissions for publication in **The Journal**. The following is an author style guide for the benefit of anyone wishing to contribute. In order to save time, expedite the mechanics of publication, and avoid confusion, please adhere to these guidelines:

1. All copy is to be typed, double spaced, on one side only using white paper and a black ribbon in standard English.

2. All pages of the manuscript are to be consecutively numbered.

3. Two copies of each manuscript are required.

4. Refer to all graphics, diagrams, photographs, or illustrations in your text as Figure 1, Table 1, etc. Be sure to identify all material. Illustrations cannot be redrawn. Accordingly, be sure that all lines are black and sharply drawn and that text is large enough to be legible when reduced to 4.25" in width. Good quality photocopies are acceptable of sharply drawn illustrations.

5. Submit a recent glossy black & white photograph (head to chest). Make sure that your name and address is on the back. Photographs, illustrations, or other submitted materials cannot be returned unless postage is prepaid.

6. The editorial staff will edit manuscripts for publication, however galley proofs cannot be submitted for author approval. Authors are encouraged to seek editorial comment from their collegues before submission.

7. Enclose all material, unfolded, in a large envelope. Use heavy cardboard to prevent bending.

8. All articles shall be written using Metric-SI units. Common measurements will be accepted at the discretion of the editorial staff.

9. Send all material in one mailing to:

Jon M. Duff, Editor
The Engineering Design Graphics Journal
355 Knoy Hall of Technology
Purdue University
West Lafayette, IN 47907

**REVIEW OF ARTICLES**

All articles submitted will be reviewed by several authorities associated with the technical content of each paper before acceptance. Current newsworthy items, or comments, will be accepted at the **discretion** of the editors.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

ENGINEERING DESIGN GRAPHICS JOURNAL

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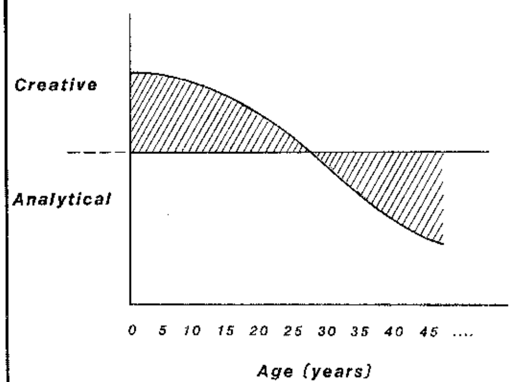


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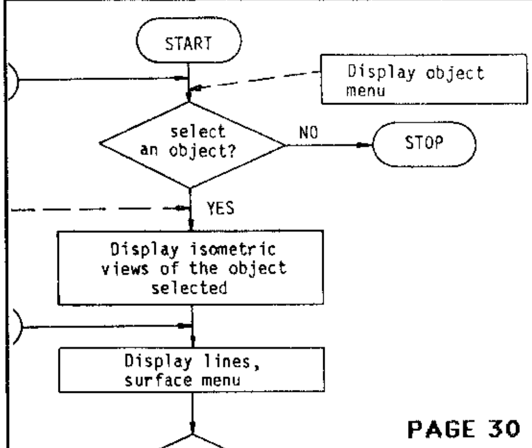


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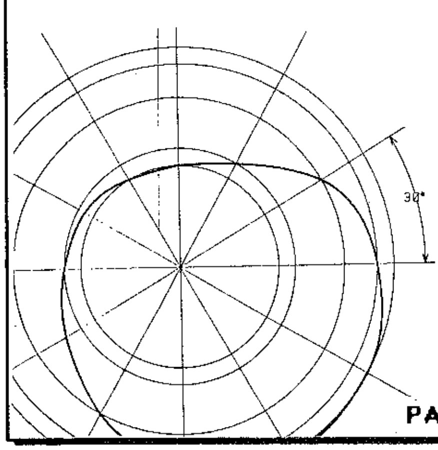


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Cover: Illustration from <u>The Measure of Man</u>

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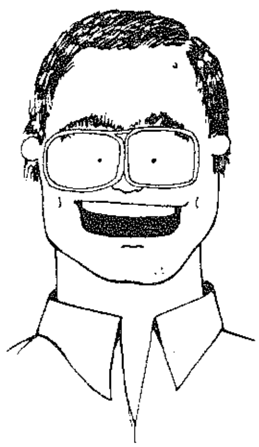
# EDITOR'S PAGE

## THE COVER......

Some things are always better, somehow simpler or more elegant in the abstract. Take human factors for example. You can model behavior and man-machine interface but you really don't know the truth until the conceptual case is tested by the reality.



Few of us had any idea that working with computers, in our case making graphics on a computer, would be so fatiguing, both mentally and physically. I suppose this is somewhat due to CADD systems being designed by individuals who spend their days in front of a terminal, who always have, and who always will. We "pre-CADD" types never did, and now hope we never will.

**factors that are anatomically correct may be functionally incorrect**

Why is this activity so tiring? Let's compare the old days to new days. In the old days if you wanted a drawing, you got up from your desk or table, walked down the hall or across the street, to "pull" the drawing from a file. Or, you stood at a counter while someone looked up an aperture card. What is missing from the computer technology?

1.**Physical Activity.** The physical boundaries of the computer workspace are confined. You transfer data, merge drawings, file, edit, or dispose from you seat. You can access so much of the industrial information base without leaving your station that there may be days or weeks where your major physical activity is walking in from the parking lot in the morning and back at night.

2.**Interpersonal Contact.** On the way to pull the drawing you might stop by someone's desk to discuss a problem, or to joke, or flirt. You might combine trips so that you drop off a drawing on the way and visit the shop floor on the way back. You move through real physical space rather than electronic space.. Most people need this contact with other people to keep their sanity.

The reason I bring this up is the stooped-shouldered, squinty-eyed look of many of our confederates, and the lower back pain that seems to accompany the acceptance of the technology. Constant use of the technology-and by constant I mean 6-8 hours per day, 5-6 days per week-seems to have serious negative effects. Large motor activity off the job is more important than ever, as are broad global visual tasks. It may mean that some of the human factors that are **anatomically** correct may not be **functionally,** correct. We need to consider the **quality** of life we need at work to be healthy human beings.

## THE SHAKE-UP.....

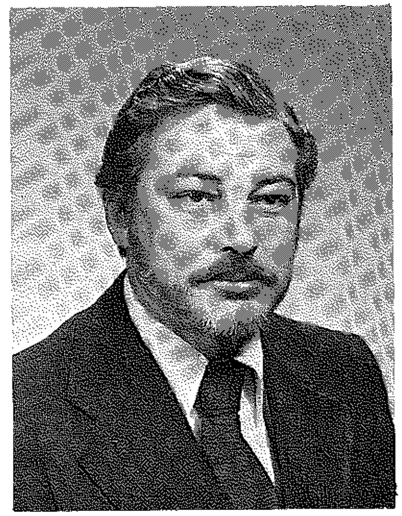
An observation on the recent contractions in the CADD equipment industry. It may be that we have reached the saturation point for CADD systems based on what I call "2nd level of development." ( Batch graphics was the first, command language graphics is the second) Most current systems are based on computing hardware for input and editing rather than being based on the way that humans make graphics. Current systems require a major investment to be competitive causing many companies to say " I'll wait until they get this thing to the place I can afford it and understand how it works." And so we'll wait a couple of years until CADD systems move into the 3rd level.

## GRAPHICS.......

The trip to AMGRAF in Kansas City during the Mid-Year Meeting was quite illuminating. AMGRAF, for those of you who weren't at the meeting is in the business of merging text and computer graphics to make technical documentation. It pointed out that computer graphics' home is not necessarily in engineering design, lest we forget that documentation is a major function in the engineering process. It makes alot of sense when you merge text and graphics.

Continued on Page 8

# Chairman's Message



Garland K. Hilliard
North Carolina State University

Engineering Design Graphics is alive and well. Those in attendance at our Mid-year Conference in Kansas City can attest to the above statement. From my experience as a member, it is easy to see why the oldest Division of ASEE has survived in the midst of adversity and continues to thrive on the challenge of new technology. In my view, it is the professionalism exhibited by our membership, coupled with a down-to-earth perspective and approach to problems, as well as our dedication and perseverance in just plain hard work. That combination of human qualities, working in concert, has kept the Division in the forefront of not only applied and theoretical graphics, but teaching techniques, freshman programs, design and computer graphics as well.

As your Chairman, I have been afforded the opportunity to overview the efforts of so many of you who keep the Division not only alive and well, but on the cutting edge of excellence. Nowhere are the intricacies, innerworkings, growth and renewed personal relationships more prominently displayed than at our mid-year and annual meetings. I am simply amazed at how well an organization as large as ourselves (approximately 500 members) functions with relatively little effort by the Chairman. Now, you know it has to be a good thing when that many people believe so strongly in what they share that success is eminent and preordained regardless of direction or attempts to forestall it.

Elsewhere in this issue or in an upcoming issue are the highlights of our conference in Kansas City. Betty Butler, our host at UMKC, Jerry Smith and Ron Barr, our program chairpeople, performed commendably in assembling an interesting, informative and varied program. Over 20 excellent papers were presented that ranged from teaching techniques to highly theoretical graphics. Most were enhanced by the effective use of visuals - slides, transparencies, TV, flip-charts and yes, even a chalk board. Judges for the Oppenheimer Award certainly had a challenging task to select the best paper.

Typical of our Division meetings and just as fruitful as the formal program are the informal gatherings of small groups of friends and colleagues. It was encouraging, if not a delight, to see so many of our members discussing issues and concerns, comparing programs, and just having a good time at the bar, around the coffee urn, in the lounge or over a meal. Anyone who has long been a member of the EDGD knows that this is where many answers are discovered and friendships are restored. It is also where we are reassured that we have more commonalities than differences in our problems, hopes and dreams.

Reports from those who attended indicate that the International Conference on Engineering and Computer Graphics held in Beijung, China, was an overwhelming success. A feature article appears in this or an upcoming issue of the Journal. Again, a special thanks goes to our own Steve Slaby, Chairman of the U. S. Organizing Committee. Already plans are underway for another international conference. Tentatively, the conference will be held in Austria in two or three years. Look for it and plan to participate.

Of current interest and ongoing challenge for most of us is the impact of computers and especially Computer Graphics as the technology rapidly emerges and often appears to overwhelm us. The challenge, however, is being met head-on as evidenced by the increasing number of excellent papers at our conferences and in our Journal. The papers reflect how each of us is wrestling with the challenge in our own way, given our own circumstances at our own institutions. There appears, at this point, to be no perfect or universal answer to how we incorporate the computer into engineering design graphics education. And if there does appear to be a perfect solution today, it is all but antiquated tomorrow as newer, faster, and less expensive alternatives become available.

Meet the challenge - we must and will. Prevailing over all our thoughts and actions as we approach the new technology, however, is that what we teach is not lost in the urgent tide of a new way of doing it. We must be ever-mindful that our students need to be able to visualize, to understand geometric principles, graphic theory, and drawing standards and conventions. And, yes, until technology develops they still need to be able to whip out quick sketches on the back of an envelope, a napkin or in the sand. Let us not lose perspective of what we teach and industry demands. Analogous to computer graphics is word processing. Who would presume that one could become proficient in word processing without a command of English, sentence structure, spelling, etc.? More important than the machine is our students' ability to think creatively and effectively apply thoughts for the "benefit of mankind."

Garland

# EDGD Mid-Year Meeting Getting People Together in Kansas City Graphics

Row 1: Wallace Franklin, Miher Das, George Eggman, Richard Marrelli
Row 2: Frank Garner (AMGRAF), Richard Latimer, Jon Duff, Ron Barr
Row 3: Mike Khonsari, Pete Miller, Tour of Amgraf

# Personalities

## people and places

# Education

Row 1: Chancellor Russell (UMKC), Len Nasman, Bruce Harding,Gaey Bertoline, Rollie Jennison
Row 2: Pat Kelso, Truman Home in Independence
Row 3: Josann Duane, David E. Roth

# INTERNATIONAL MEETING

Professor Steve M. Slaby of the Civil Engineering Department of Princeton University recently returned from his third trip to China where he, and several other members of the EDGD,participated in the International Conference on Engineering and Computer Graphics (ICECG). This is the second major international conference in this field of Graphic Science-the first taking place in Vancouver, Canada in 1978.

Professor Slaby was the Chairman of the United States Organizing Committee of the ICEG and was also the United States-European coordinator of the conference. Larry Goss represented the EDGD as immediate past Chairman, presenter, and session moderator.

The conference was held under the auspices of the China Engineering Graphics Society and The Engineering Design Graphics Division of The American Association for Engineering Education. Taking place in Beijing from August 27 to September 1, 1984, over 200 scholars participated from 12 different countries.

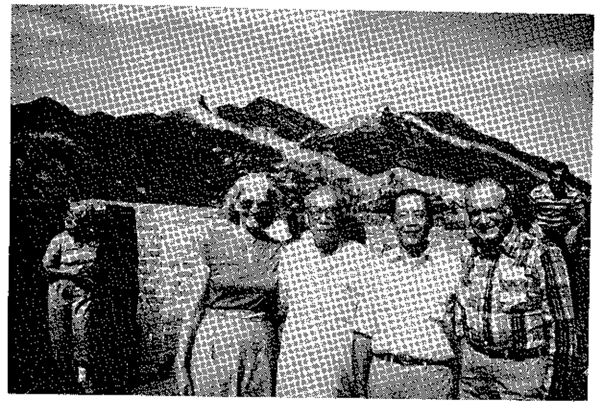
## SLABY LECTURES.....

In December 1981, Professor Slaby was invited by Professor Zhu Fu Xi of the South China Institute of Technology to present a series of lectures on Four-Dimensional Descriptive Geometry. It was during that time that the suggestion was made to hold the Second International Conference in China; a suggestion that was enthusiastically received by the Chinese officials.

## CONFERENCE.....

A formal reception opened the conference in the Beijing Friendship hotel where an elaborate Chinese buffet was served.

The conference was considered to be eminently successful by all of the participants and resulted in the publication of the "Proceedings of the International Conference on Engineering and Computer Graphics." Because of the success and enthusiasm of the conference, tentative plans have been initiated for the Third International Conference in Graphic Science to take place in Vienna, Austria, in 1987.



At The Great Wall of China
(Left to Right)
Karin Slaby, Prof. Zhu Fu Xi and Prof. Zeng Damin of the South China Institute of Technology, Steve Slaby


Conference Room at the Fragrant Hills Hotel
Beijing, China

EDGJ

## EDITOR'S PAGE

Continued from Page 4

## MID-YEAR.....

Finally, hats off to Betty Butler and Jerry Smith for a super Mid-Year Meeting. Kansas City appears to be one of the best-kept secrets around!!!

EDGJ

# DIVISION NEWS

## FOR YOUR INFORMATION

Winner of the **Oppenheimer Award** for the best presentation at the Kansas City Mid-Year was **Gary Bertoline** from Wright State University. Great job, Gary, and we hope you will be a regular contributor to our meetings and the EDGJ. The majority of the presentations included **technical papers** for distribution at the sessions, something that will be **required** for presentations in the future.

The ASEE **national meeting** will be held June 16-20, 1985 in **Atlanta** with Georgia Tech as host. A full slate of graphics sessions is planned. Outgoing chairman **Garland Hilliard** will turn over the reins of The Division to **Bob Foster** in Atlanta.

Look for a piece by **Betty Butler** in the Spring Journal on the non-conference activities associated with the **China Conference**.

Make sure each of you casts your **ballot** for division officers when it comes in the mail this spring. Only by participating in the decisions of The Division can you assure that its course is well-charted.

For those of you who participate in the national or mid-year meetings only infrequently, consider a more active involvement: Submit regularly to **The Journal**, attend section meetings and hold local seminars and workshops.

# JOBS POSTED

## HEAD, DEPARTMENT OF ENGINEERING GRAPHICS

The College of Engineering at The University of Alabama invites applications and nominations for the position of Head of the Department of Engineering Graphics. The department is responsible for the graphics offering associated with programs in engineering and engineering technology. In addition to basic engineering graphics, the department offers courses in construction procedures, construction drawing, production illustration, and computer graphics. Duties will include instruction as well as departmental administration and development. The position requires a person with an engineering degree along with experience in Engineering Graphics, experience with Computer Graphics and/or Computer Assisted Design and Drafting (CADD), and an ability to develop and administer an academic department. A Master's Degree is required and a Doctorate will be given preference.

The University of Alabama is a 15,000 student university located in Tuscaloosa, a congenial city of 75,000 featuring excellent weather and living conditions. Rank and salary will be commensurate with qualifications. Review of application will begin in January, 1985, with an anticipated employment date of August 16, 1985. Applications will continue to be accepted until the position is filled. Send letters of application, professional resumes and names of three references to:

**Dr. J.O. Doughty, Chairman**
**Engineering Graphics Search Committee**
**P.O. Drawer ME**
**University, Alabama 35486**

The University of Alabama is an equal opportunity/affirmative action employer.

See JOBS on page 14

# GRAPHICS COMPETENCIES AS DETERMINED BY THE DELPHI METHOD

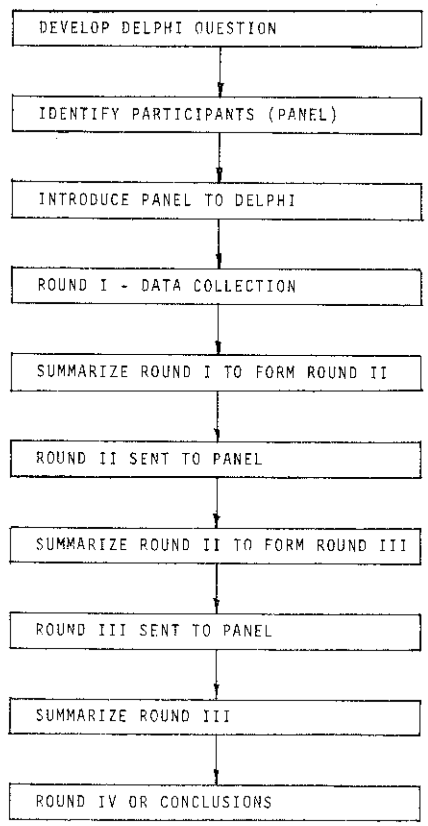
Mary A. Sadowski Ph.D.
Technical Graphics
Purdue University

The Industrial Illustration program at Purdue University has been in existence as a two-year Associate degree program for 20 years. Until the fall of 1984, the facilities and most of the equipment were as old as the program. During the summer of 1984 the Technical Graphics Department moved into a new facility with new equipment. With the prospect of new facilities, new equipment, and the possibility of a four-year program, the Technical Graphics Department began to look at the future of graphics, rather than simply looking at what was currently being done. Since changes in the curriculum would affect students who would not be entering the work force for several years, it was decided to use a Futures technique to conduct a needs assessment. The Delphi method was used to collect data which could be used to help determine a curriculum which would satisfy the needs of future students.

The Delphi technique was developed in the early 1950's by Olaf Helmer and Norman Dalkey in conjunction with a United States Air Force sponsored Rand Corporation study. Its purpose was to obtain the most reliable consensus of the opinions of experts using a series of questionnaires interspersed with opinion feedback.

The Delphi technique is considered a Futures research technique since the focus of a Delphi survey is on the future rather than the past. The technique is named after the Greek oracle of Delphi. A Delphi survey does not attempt to predict the future, rather it attempts to obtain a consensus of opinions about an important future issue.

Originally developed and used by the Rand Corporation, the Delphi has been utilized in industry, government, and most recently education. Delphi has commonly been called "consensus without confrontation." A panel of respondents knowledgeable in the area being researched is utilized to gain a consensus. One of the major concepts behind the Delphi is to provide an opportunity to communicate without the face-to-face problems that often accompany committee work. The Delphi allows people from a wide geographic range to interact with one another without the hassle and expense of travel and meeting schedules.




**PURDUE TECHNICAL GRAPHICS DELPHI**
November 1983-March 1984

The Delphi is often described as a process. Each Delphi involves a panel of respondents who are expert in the field being surveyed. The respondents are selected by the researcher and contacted in advance of the actual survey to determine if they will be willing to participate. All Delphi's are conducted in writing, utilizing a series of rounds of instruments called opinionnaires. Each round of the Delphi is compiled and the results and comments are returned to the panel for additional responses and comments. These rounds are continued until a consensus has been reached or a dichotomy identified.

The Delphi has been used primarily in the business / industry and government settings. It is only in the past 15 years that the educational community has begun to employ this technique. The process has been applied to prioritizing personal values and social goals, explicating the advantages and disadvantages associated with potential policy problems, evaluating budget allocations, examining the significance of historical events, and distinguishing and clarifying perceived or real human motivation. It may also be used to determine or develop a range of possible alternatives as well as to explore or expose underlying assumptions or information leading to differing judgments. It may be used to correlate informed judgments on a topic spanning a wide range of disciplines or to educate a respondent group as to diverse and interrelated aspects of the topic.

The Delphi is considered an appropriate technique when the problem does not lend itself to precise analytical techniques and when the individuals involved have no history of adequate communication or represent diverse backgrounds in both experience and expertise. The Delphi might also be appropriate when dealing with groups that are larger than those that can effectively interact face-to-face or when time and cost make group meetings unfeasible.

## DELPHI QUESTION

The question developed for the Technical Graphics Delphi was "What entry level competencies will be needed by the Technical Illustrator in 1989?" The year 1989 was selected because it is generally easier to discuss the future in finite terms rather than to discuss the future in general. Another consideration was that it will be five years before results could be implemented and students graduate from a program utilizing the results.

## PANEL OF PARTICIPANTS

The panel of respondents selected for this Delphi included 21 professionals from 11 states and 21 cities. The panel was divided into four groups which included educators, illustrators in the industrial setting, illustrators in the architectural setting, and supervisors of illustrators. It was hypothesized that the four groups of illustrators would respond differently to the initial Delphi Opinionniare.

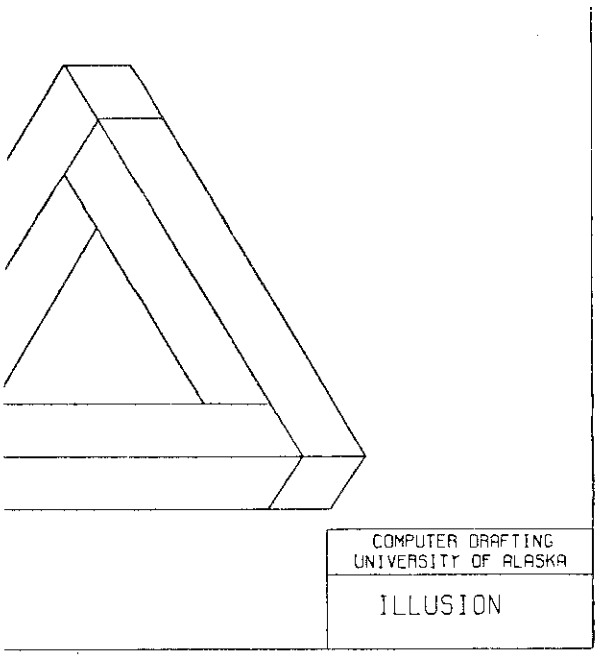
**an attempt to obtain a consensus of opinions about future issues**

COMPUTER GRAPHICS (DRAWING) - Rate the importance of these computer drawing skills as future entry level competencies.

| LOW | | | | | HIGH | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 38. Create a graphics file |
| 1 | 2 | 3 | 4 | 5 | 6 | 39. Save a graphics file |
| 1 | 2 | 3 | 4 | 5 | 6 | 40. Get a directory of graphics files |
| 1 | 2 | 3 | 4 | 5 | 6 | 41. Create 2-D geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 42. Create 3-D geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 43. Create, save, and assign figures |
| 1 | 2 | 3 | 4 | 5 | 6 | 44. Change drawing scale |
| 1 | 2 | 3 | 4 | 5 | 6 | 45. Change drawing window (pan, scroll, zoom) |
| 1 | 2 | 3 | 4 | 5 | 6 | 46. Translate geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 47. Rotate geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 48. Know edit geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 49. Know plot geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 50. Use function keys |
| 1 | 2 | 3 | 4 | 5 | 6 | 51. Use puck and graphics tablet |
| 1 | 2 | 3 | 4 | 5 | 6 | 52. Use light pen |
| 1 | 2 | 3 | 4 | 5 | 6 | 53. Digitize existing geometry |
| 1 | 2 | 3 | 4 | 5 | 6 | 54. Use text (line) editor |
| 1 | 2 | 3 | 4 | 5 | 6 | 55. Create command files |
| 1 | 2 | 3 | 4 | 5 | 6 | 56. Merge text with graphics |
| 1 | 2 | 3 | 4 | 5 | 6 | 57. Recognize and understand the common terms (i.e., edit, layers, grid) |
| 1 | 2 | 3 | 4 | 5 | 6 | 58. Have experience on a computer-aided graphics system |
| 1 | 2 | 3 | 4 | 5 | 6 | 59. Know how machines draw |
| 1 | 2 | 3 | 4 | 5 | 6 | 60. Know how people make machines draw |
| 1 | 2 | 3 | 4 | 5 | 6 | 61. Know programming in basic, pascal, or fortran |

**EXAMPLE OF OPINIONNAIRE ONE**

THE FUNDING PROBLEM: Each academic Dean had to anticipate the computer needs of his students, two years in advance, and obtain funds to pay for them. When a student used the computer I charged the academic department which was the source of the assignment. Real money was transferred from the academic department to mine. Upon each budget squeeze, many academic departments would reallocate their computer funds for other use: such as salaries for teaching assistants. I would have to convince the appropriate Dean to redivert the funds if his students were to use the computer. Dean Behlke, of the Engineering School, was alone among the academic deans in obtaining and maintaining money for student computer use in spite of the strong adverse pressures of a poorly funded academic institution.




AVAILABLE EQUIPMENT: The University leased a medium sized batch processer, an IBM 360/40, when it established the Center. It also owned an IBM 1620 which has a Calcomp drum plotter attached to it. For the needs of the research groups we had written software that enabled the IBM 1620 to be used like an offline plotter. While we used punched cards to carry plot information from one to the other, the software looked just like we were preparing a plot tape on the IBM 360/40 for use on a Calcomp tape driven plotter.

Things were a bit grim for a music student who wanted to use the computer. About all I could do was determine if there was skill development potential and then offer some computer room employment which provided computer time as an employment benefit. I was restricted in hiring such students by the need to somehow sell additional computer time to cover the added cost of their salaries.

In the late 1960's Dean Behlke came to me and asked what my Center could do for his drafting classes. I promised Behlke I would have a usable teaching activity in computer graphics for him. At the moment, I really had no idea how I would produce it. The University provided no budget for software, nor for its development for the needs of the academic programs. But I also taught a senior level computer programming course for the Engineering School and I decided that the development of the Alaska Drafting System would be an excellent task for my students. By mid 1971 the system was completed and put to use. It was still in use when I left the University in 1982.

DESIGN OBJECTIVES AND CONSTRAINTS: From the start we knew that the system had to be simple enough to be used by a person with no prior computer experience. The drafting course was the first Engineering course taken by many students, especially those whose lack of sufficient mathematical training kept them out of other freshman Engineering courses. Any Alaskan high school graduate could be admitted to the University and try to learn Engineering. Some of our high school graduates had skill levels that reflected more the challenge of rural education rather than the students' potential individual achievement.

We designed the system so that it would be easy to edit drawings. This departed from other designs where the emphasis was having the computer primarily assist in making the initial drawing. Furthermore, an acceptable drawing had to be achievable within the bounds of a normal homework cycle. But most of all the entire development had to be completed without spending any money.

My senior course would provide only a handful of students. The programming had to be divided up into enough tasks so that each student could do one aspect of the system. The task had to be consistent with the student's skill. Furthermore I could not let these tasks grow beyond the homework time normally associated with the courses "big project" which was about one third of the course homework.

SOFTWARE SELECTION: The students came to the course with one prior semester of Fortran and ideally a year or two of experience in use of Fortran to solve problems from other courses. The course normally included design and use of Fortran subroutines and libraries. Fortran was really the only computer language considered. Not only did the students have some skill in it, and it was the most widely used language used for Engineering tasks, but more pragmatically, if I selected another language, I would have to take course time to teach it.

## migration of main-frame graphics program into a PC environment

The selection of Fortran also made available the Calcomp plot subroutines which were installed on the main computer. This meant that the user would submit data cards to a system resident on the main computer and receive a transfer deck upon completion of processing. These he would take to the offline plotter. While it would have been nice to do the whole thing on the IBM 1620 (where the plotter was located) the Calcomp subroutines were not available there. It seemed excessive, to me, to try to program around that constraint. As it was, the programming task had to be split up into rather small pieces. It is quite one thing to give an assignment of indefinite size to a professional programmer and then wait for results, and quite another to give an assignment of unbounded size to a student. The Fortran subroutine structure could enable many individual subroutines to be written by individual students and then combined into a single programming system.

USED PROCEDURE: Both the operation procedure as well as the language had to be 'user friendly', although that jargon phrase had yet to become established. The teaching faculty wished the course emphasis to remain on drafting and not become computer use.

The user would first make a rough sketch of the drawing using pencil and paper. From this he would identify graphic units, principally lines, rectangles, and circles, that could be used to make the drawing. The measures needed to describe these were determined. The user then punched a card for each graphic unit following the rules of the Alaska Drafting System language.

We prepared several copies of the control cards that were necessary to run the process. These were marked and made available to the users. Each user inserted his data cards within the appropriate location of the run deck. Instructions written on the tops of the run deck helped the user find the proper location. The punched card era did occasionally provide some small advantages. The resulting bundle of cards was submitted to the computer operator. In time they were processed and returned along with the transfer deck. This was taken by the user to the plotter that he operated himself. The time from start to finish was an hour during those scheduled times when student work was given priority on the main computer.

The drawing was then examined and corrections were made to the submission deck. The new deck was submitted once more to the main computer. This was repeated until the drawing was satisfactory.

SHAPE SUBROUTINES AND OPERATORS: The students found that they could retain sets of cards that had proven successful in producing a desired shape. These could then be duplicated and used as 'subroutines' to simplify the construction of new drawings. A more advanced student eventually wrote a program that could operate on these shapes changing their size and moving them to different locations on the drafting plate.

THE ADS LANGUAGE: The Alaska Drafting System (ADS) language was kept quite simple. This followed from the heuristic design principle that anything omitted does not have to be debugged. The commands we provided to control the drawing of the graphic units were:

PLATE
This was a two card command which produced a drafting plate with a border and with a title box. The origin was established within the border.

RECTANGLE <x>, <y>, <w>, <h> This would draw a rectangle of width w and height h with lower left corner at x, y

CIRCLE <r>, <x>, <y> A circle of radius r was drawn about the center at x, y

LINE <x1>, <y1>, <x2>, >y2> . . . <x6>, <y6> From two to six points were connected by a line

WORDS <text>, <x>, <y>,<h>
The words of the <text> were lettered beginning at x, y with height h axis. This command required two cards.

NEW PLATE Run the plot drum so that the drawing is extended beyond the tear off bar and be ready to begin drawing.

With the exception of the circle, no curved lines were provided. Many users drew curves by building them from line segments. Some students computed the locations of the individual points: the actual plot of an airfoil was used in a drawing of an airplane by one student. With the relocation operator, this could then be sized and moved to the location required by the particular drawing. Other students found it quite satisfactory to build curves by guessing at the first set of points and then refining the guesses through cut and try. The circle command, itself, actually built the circle as a 100 sided polygon. Several other commands were designed but were never widely used. They included the isometric projections of a cylinder and "block" or rectangular prism.

SOFTWARE DESIGN: The command cards were designed with a rather uniform format. They all started with an alphameric field. If anything was placed in the first column, the first two columns were used as the command code. This had the consequence of allowing imaginative spelling: LINE, LIYN, and LI worked equally well. The various parameters on the command code card were all numeric. If the first column was blank, the card was a "text" card and only a single alphameric field was considered.

A mainline program first opened the plot file and then read the cards passing the parameters in common to the subroutines. Each subroutine was written by an individual student and examined the common area for the parameters it needed and added its contribution to the plot file. The NEW PLATE command invoked dumping of the plot file into the transfer deck.

MIGRATION TO TIMESHARING; Several changes were required when the University retired the IBM batch processer and obtained a Honeywell 66/20 interactive time sharing system. There were two disadvantages: First of all, the user now needed to know some sort of editor before he could type in his plot data. Secondly it took longer for the beginner to learn how to combine his plot data file with the command files and submit them. Offsetting those disadvantages was the general increase in previous computer experience of the beginning students. In punching cards we had insisted that the user punch the numeric values within certain specified card columns. This is impractical on a terminal and so we added a subroutine to enable the input to be column independent. The Engineering School purchased a cathode ray tube graphics terminal and it now became possible to preview the drawing on it.

THE CHALLENGE OF THE PC: Alaska became very aggressive in the introduction of personal computer into rural education. These have quite superior graphics potential. It has been proposed that the Alaska Drafting System be migrated once again to the personal computer configuration which has been widely selected for use in the rural schools. The concept of a drawing generator that produces a natural language script has some strong educational potential. The script would need to be debugged and improved through editing. It would be used not unlike LOGO but for an older target age group. It should also move more rapidly to a more accurate drawing such as the plans for a cabin.

The teaching of computer literacy concepts through teaching programming in BASIC has considerable problems in the Alaskan "bush": The indigenous cultures are rather devoid of computational tradition. Yet the graphic tradition is rich. A challenge of education within this milieu is to avoid creating a cultural barrier to learning by unwise introduction of motivating material which is primarily computational. As FORTRAN is not a widely used language for PC's a language change is being considered. BASIC and Pascal are being considered.

This change from batch mode to interactive graphics on micro-computers awaits a new group of University of Alaska students to develop and implement the system.

<u>Editor's Note:</u> This paper was included in the proceedings from the International Conference on Engineering and Computer Graphics. It was included in this issue for several reasons: 1) to recognize that the tools of graphics have changed from manual to electronic in all corners of engineering education; 2) to review computer graphics education in a historical perspective 3) to demonstrate the need for transport ability in software and course wave. The <u>elements</u> of computer graphics can be taught independent of the equipment, and must be, if we are to be able to adapt to rapid changes in the technology.

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REPRESENTING GEOMETRY

# ON DEFINING CIRCULAR AND ELLIPTICAL CYLINDERS BY ORTHOGRAPHIC/ORTHODIRECTIONAL* PROJECTION

by Robert P. Kelso

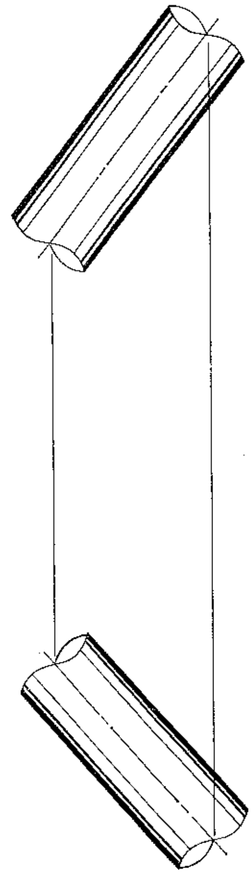
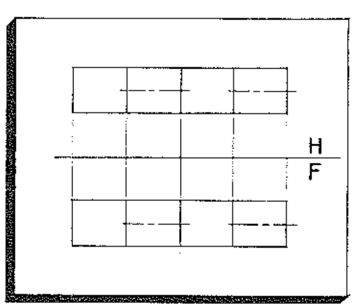


FIG. 1

The cylinder in Fig. 1 may give the illusion of being right-circular (an illusion helped by the diameters being equal length in both views) but it might be a right-elliptical cylinder. Fig. 2 demonstrates how this may occur. (Hereafter "right-circular" and "right-elliptical" are referred to simply as "circular" and "elliptical.")

Defining a cylinder in space by Orthographic/Orthodirectional* Projection requires adjacent views showing (1) the axis and (2) the BASE.

A straight forward technique of defining the cylinder as circular is to project the TL view of the axis, and in that auxiliary to arbitrarily (since there are no point distances to transfer) draw a cylinder with a diameter equal to that as seen in the Principal Views, and to construct a Base-EV perpendicular to the TL axis. From this Axis-TL-View then project an Axis-Point-View and arbitrarily (again there are no point distances available to transfer) draw a circle to represent the EV of the cylinder. From the two auxiliaries it is now possible to project (points on) the circle back to the Principal Views where circular bases will appear as ellipses. Fig. 3.



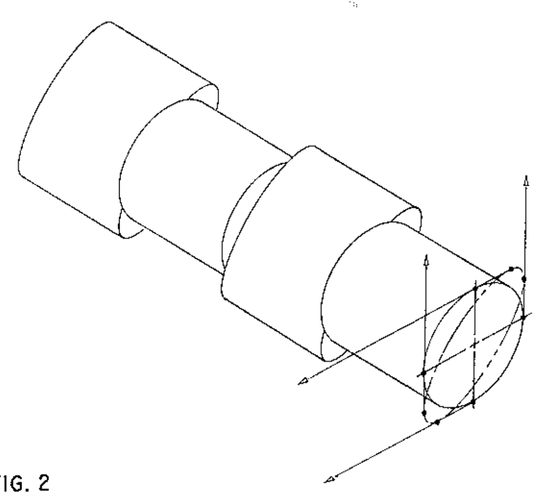



FIG. 2

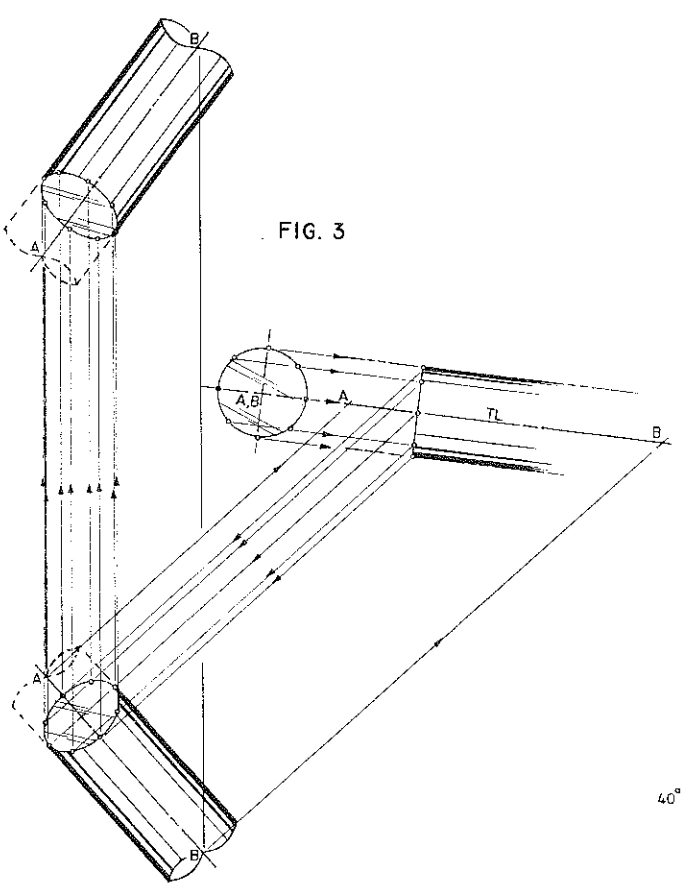
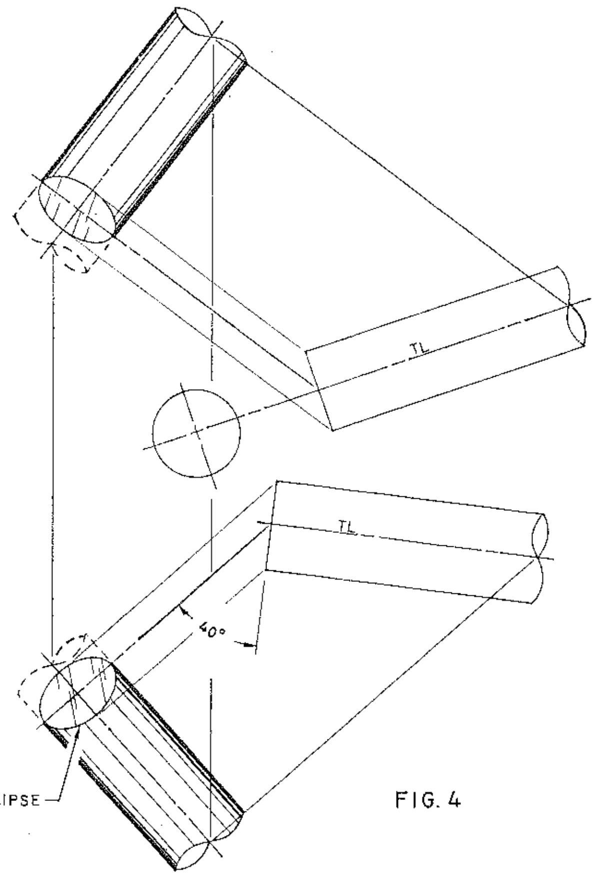



FIG. 3




40° ELLIPSE

FIG. 4

A commonly used "commercial" method is to project a TL Axis View from each of the Principal Views and in each of these auxiliary views draw a cylinder with a diameter equal to that seen in the Principal Views and construct an EV Base perpendicular to the axis. From each primary auxiliary then "project" the base ellipse back to each respective Principal View by using an ellipse template with an ellipse-template-angle determined by the projection-line angle with the EV-Base-plane. Fig. 4.

Because ellipses (including those which represent bases of circular cylinders) require more effort to project, it is desirable to have bases represented as circles. This is achieved for circular cylinders by (1) drawing only one Principal View of the cylinder, the axis being in any general position (direction) and in that same view (2) drawing a circle on the cylinder to represent the base, then (3) drawing projection lines perpendicularly from the axis into what will become the first auxiliary view. Then in the first auxiliary (4) drawing a straight line (to represent the EV of the base) at any general direction and length but between and intersecting the projection lines of the circle limits. Then (5) Reflecting A Projection Line Off Of The Base EV--thereby for the first time, establishing the direction of the TL axis in the auxiliary. Finally (6) constructing a second Principal View adjacent to the initial Principal View. Fig. 5.

**the elliptical cylinder is the general, not the special case**

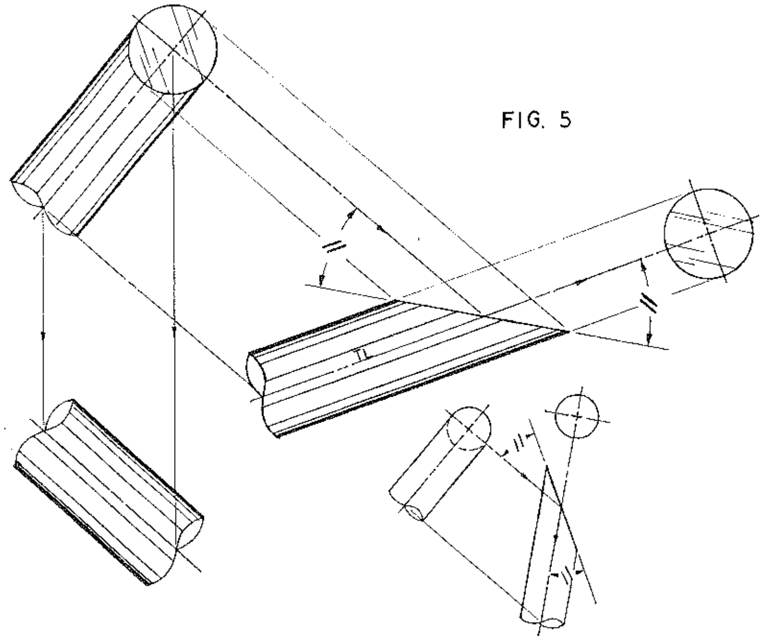



FIG. 5

Note, however, that the final Principal View in Fig. 5 will show the base as an <u>ellipse</u>! Is it possible, then, to define a circular cylinder in a general position such that the base appears as a circle in one Principal View and as an EV in an adjacent Principal View? The answer is: NO--so long as the cylinder is in a general position. <u>Fig. 6</u>.

Synopsis: A. If (1) the axis is in a general position and if (2) one Principal View shows the base to appear as a <u>circle</u> and if (3) an adjacent Principal View shows the base to appear as an <u>ellipse</u> then the cylinder may be either <u>Circular</u> or <u>Elliptical</u>.

B. If, however, (3) above reads: "... an adjacent Principal View shows the base to appear as an <u>EDGE</u> ..."-- then the cylinder may <u>only be ELLIPTICAL</u>.

It follows that the Base EV in a Principal View is a special case of the "ellipse-view" general-condition. Therefore, if an example cylinder is drawn to show its base to appear as a circle in one Principal View and as an edge in an adjacent Principal View, then it should be properly notated on the drawing (or text) that the cylinder is propitiously constructed (situated) to cause these two special conditions to exist in adjacent views. Also, since most people are programmed to expect an "everyday cylinder" to be circular it is suggested that it should also be noted whenever the cylinder is elliptical even though an elliptical cylinder is the general geometric condition rather than the special case.

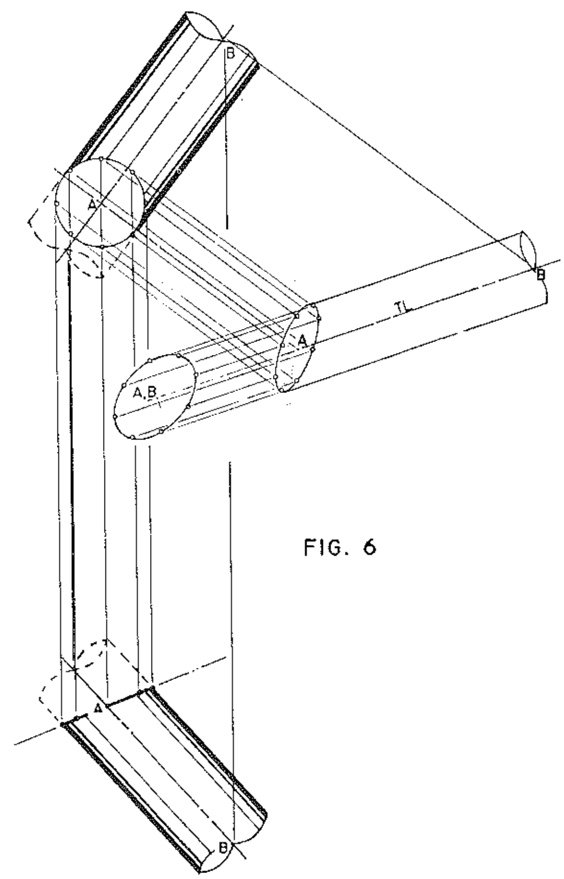



FIG. 6

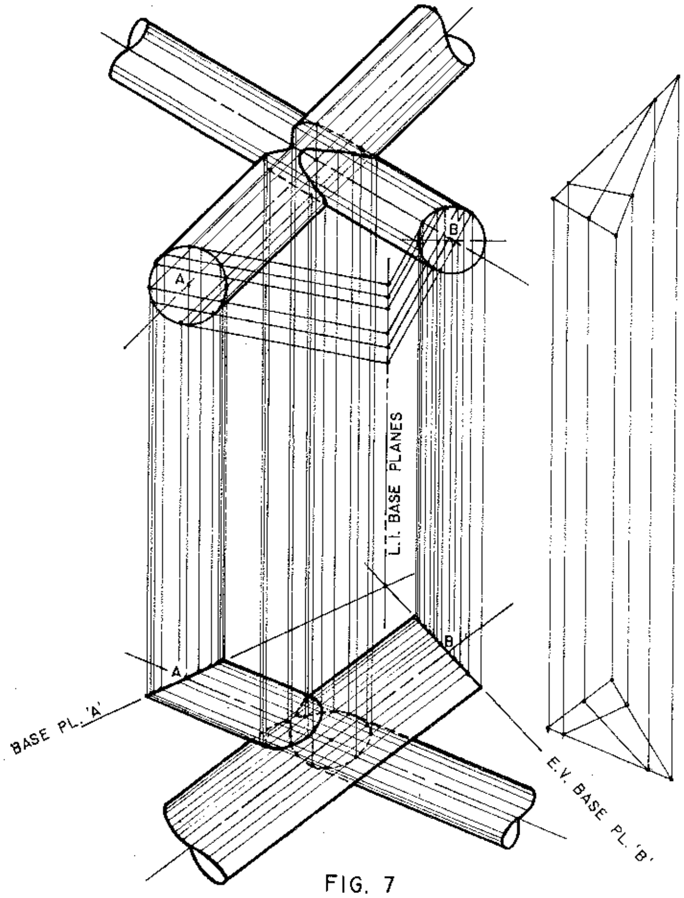



FIG. 7

Often even greater special cases are used in texts without notation in illustrating examples of "Intersections" and "Tangencies". TWO cylinders are depicted with circular appearing bases in one Principal View, the bases formed by their EVs being a common principal plane in an adjacent Principal View. ONE elliptical cylinder with circular/EV-appearing bases may, if properly notated, be tolerated for convenience of drawing but to have two cylinders in general positions to appear as such--ESPECIALLY WITH THE EV BASES BEING ON A COMMON PRINCIPAL PLANE--seems untenably special since using INCLINED base planes at the least are feasible and facile. Fig. 7.

(The appendix demonstrates the steps in creating "circular/EV" appearing bases in two adjacent Principal Views.)

*Orthographic Projection is defined as a projection perpendicular to a Plane of Projection.

Multiview Projection means orthogonal projection but in the past has also implied those views achieved only by 90º Projection-Line rotations in space. Since the computer, for graphics, does not necessarily show this scheme of 90º - spacial - "stepping" but still needs the word in its broader sense, we here use ORTHODIRECTIONAL to mean: "90º PROJECTION-LINE ROTATION IN SPACE."

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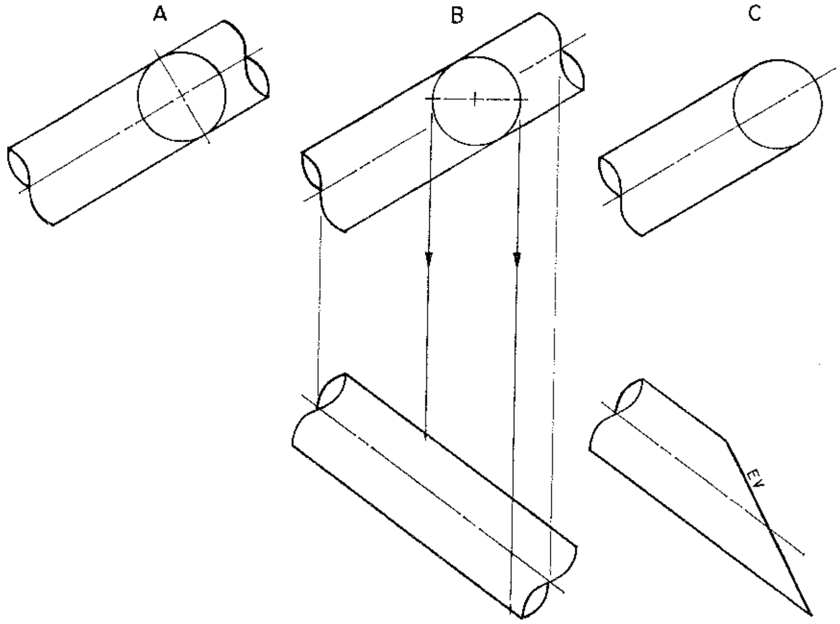


APPENDIX

# STIMULATING CREATIVITY IN ENGINEERING DESIGN EFFORTS

by
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The Design Process includes creation of alternate, feasible design solutions for the problem under consideration - yet how does one 'create' these alternate designs?

Philosophers, psychologists, sociologists, engineers, businessmen, artists and many others have devoted much effort in their attempts to understand and stimulate creativity in human beings. Many discussions, journal publications and books have been directed toward the development of an appropriate definition of creativity, thereby indicating the complexity of this phenomenon.

It is our contention that every person can be creative; as Osborn (1963) stated, creativity is a universal talent. We each bring to engineering our unique perspective, experience, education and creativity. In fact, society does not require another mechanical engineer who can solve a problem in statics or an electrical engineer who can apply Kirchhoff's laws in an analysis of a circuit - there are already tens of thousands of engineers who have the ability to solve simple problems of analysis. Society does need creative engineers who can develop new applications of scientific principles in the form of innovative products.

One might then ask: Can creativity be taught? The answer is that a person's innate ability to create can be developed through practice. We can teach ourselves to be creative through the application of the many techniques to stimulate creativity which have been developed over the years.

## A. Blocks to Creativity

Mudge (1971) has stated that a person is predominantly creative during the early (less than 24) years of his or her life and then becomes primarily judicial (or analytical) during the later years (see Figure 1a). Papenek (1965) noted that in tests of creativity applied to persons in age groups ranging from 5 to 45 years old, it was found that a constant percentage (2%) of those between the ages of 8 and 45 were highly creative whereas 10% of the 7-year-olds were highly creative and 90% of those who were five years of age (also see Prince, 1968). Such findings suggest that we may "lose" our creative abilities with increasing age; however, many elderly people are highly creative!

Apparently, most of us suffer from inhibitions or "blocks" to our creativity. Many of these blocks are given in Table 1 (a partial listing of the material given in Gregory, 1967). As can be seen, we and our environment apply these blocks to our minds. The formidable task awaiting us is to minimize or eliminate these inhibitors if we are to become truly effective design engineers (see Figure 1b).

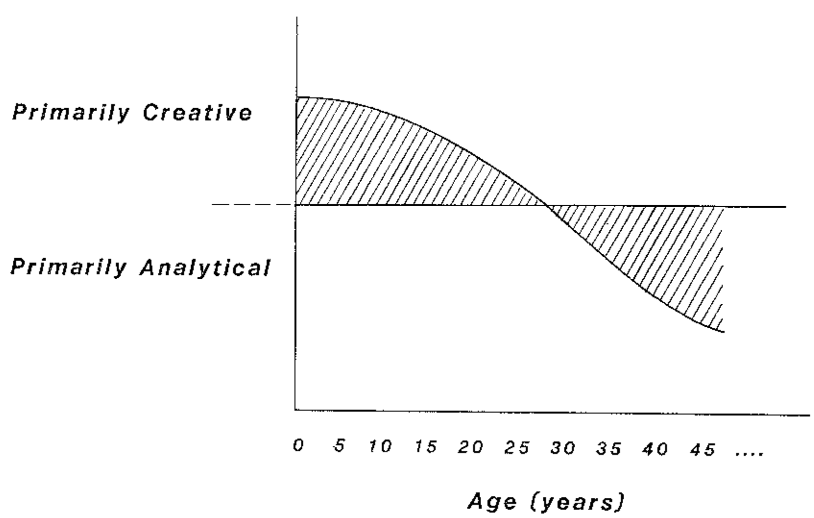



Figure 1a: Creativity Time-Line

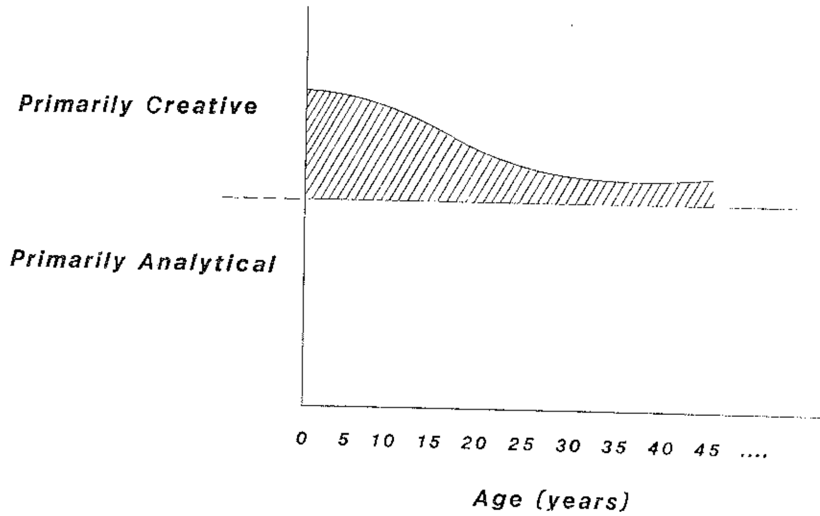



Figure 1b: Maintaining Creativity

## B. Crucial Guidelines

Before we begin to review some effective techniques for stimulating creativity, it is imperative that we recognize the following facts which are crucial to our ability to be creative:

(1) Although one's experiences can lead to some of the blocks to creativity identified in Table 1 [e.g., "functional fixedness" -, see Voland (1983a)], these experiences are necessary if we are to recognize the needs of society to which we should direct our design efforts.

Experience, education, knowledge, information and data are necessary for creative engineering designs. Engineers need to be familiar with as many scientific principles, experimental results, manufacturing methods, design components, etc., as possible in order to have access to this "pool of information" from which to extract ideas for "idea-stimulators". We also wish to avoid "re-inventing the wheel" [see Von Fange (1959), Hix and Alley (1958) and Voland 1983b)].

One must record a new idea immediately (see Von Fange, 1959); keep a notebook and a pen available for recording purposes.

All of the techniques described in the following pages (and other techniques) will not be useful to an individual (Von Fang, 1959). Each of us needs to discover which technique(s) are most successful for us and for those with whom we work.

Each of us needs to be encouraged in our creative efforts; therefore, we should encourage one another (Osborn, 1963; Hill, 1983).

## C. Techniques to Stimulate Creativity

The following techniques for stimulating creative ability (and overcoming inhibitors) do not form an all-inclusive list; other techniques can be found in the literature. In addition, researchers are continually reporting new approaches which are successful for some people. The techniques given below have been chosen because of their popularity, simplicity, uniqueness and/or applicability to engineering design efforts. Examples are given for many of these techniques in use.

Alphabetical Listing Association (See 'RULES 24, 25, 26') described below.

As Von Fange (1959) notes, the early Greeks believed that new combinations of concepts and ideas can be achieved through the process of association via similarities or contrasts.

Example: Consider the problem of hanging a framed picture on a wall. One might consider such similar "hanging" problems as (1) hanging drapes, (b) hanging potted plants, (c) spiders clinging to the ceiling, (d) suspension bridges, etc. Contrasting concepts can remove the need for developing the solution to the "original" problem, e.g., decorate the wall itself so that framed paintings are not needed.

Attribute Listing Developed by Robert P. Crawford, this technique allows one to focus upon the various attributes or characteristics of an object, product, concept, situation or problem. One can then change or relate these characteristics [see Crawford (1954, 1964), Osborn (1963), Parnes (1976), Parnes, Noller and Biondi (1977)].

Example: Consider a simple product such as a pencil. We can focus upon individual characteristics such as the materials (wood, lead, rubber, metal, paint), eraser, tip, shape, length, diameter, relationship to the user's hand and interaction with writing surface. We can then concentrate upon possible modifications of these attributes and their interrelations.

Bionics In Bionics, one searches within nature for design concepts. As Papenek (1969) observes, nature is a handbook of designs that are inexhaustible in both number and application [also see Parnes, Noller and Biondi (1977)]. Birds, animals, plants and micro-organisms can each provide the design engineer with inspiration.

Examples: Fur on animals for insulation suggests the use of hair (perhaps artificial ) on coats, blankets or housing to ensure warmth. Bats use echo for flight navigation; both radar and sonar are based upon this concept found in nature. Fibers in plants provide structural integrity and paths for nutrients; "fibers" in man-made structures are used for similar purposes.

Black Box Technique Developed by the product design group at General Electric (Gregory, 1967), this technique requires one to identify the objective of a product or concept as the output of a "black box"; the inputs (including specifications) to this system are then identified. Finally, one manipulates a variety of concepts or relationships within the "box which allows the system to produce the desired output from the given inputs. The use of scientific principles and facts which relate physical variables can be valuable in developing relationships between the input and the system output [ See Hix and Alley (1958) and Voland (1983b).]

Brainstorming This classic technique, developed by Alex Osborn in 1929 [Von Fange (1959)], is based upon deferred judment, i.e., ideas are generated by a group or an individual but there is no evaluation of any idea during the creative idea-generating session. Characteristics of this approach are as follows [also, see Gregory (1967), Parnes, Noller and Biondi (1977) and Von Fange (1959)]:

> A statement of the problem is given with the focus upon one aspect or goal of the effort.
>
> Ideas are generated by the group (or by the individual) without criticism or evaluation of any kind; the leader of the group must ensure that no evaluation occurs during the session.
>
> Ideas are wanted in quantity (The reasoning for this objective is that the group is more likely to produce a set of good ideas if the total number of ideas is maximized.) Ideas may be combined, modified, incomplete, etc.; all ideas are accepted and recorded.
>
> The people in the group encourage (and not ridicule or evaluate) each other's efforts. (One criticism of this technique is that the "creators" may not be recognized for their individual contributions, thereby causing motivation difficulties [Hill (1983)]; hence, the need for continuous encouragement.)

This technique was very popular during the 1950's; research then indicated that the method of deferred judgment may be more effective for the individual working alone than for the group [Bouchard (1971)]. Additional research, however, indicated that group efforts generated more good ideas by using the deferred-judgment approach than through the use of more conventional group activities [Brilhart and Jochem (1964)]. Williams (1960) contributed a modification (known as the 'organized random search') of the brainstorming technique in which the group or individual focuses upon certain aspects or components of the topic under consideration, after which one generates as many ideas as possible within this sub-topic of the problem. Such an organization of data may help one to recall obscure facts/ideas [also, see Gregory (1967)]. Each person should investigate the effectiveness of this approach.

Checklists Another technique, also credited to Osborn, is that of checklisting [See Osborn (1963)]. One uses a series of key words, phrases or questions to stimulate ideas about the problem or product under investigation. Table 2 presents a checklist of stimulators [based primarily upon that given by Mudge (1971)]. Osborn (1963) and Mudge (1971) suggest using dictionaries; classified telphone directories, book indices and other organized lists of data can also be very helpful [Osborn (1963)]. (Notice that some of the checklist items can also be very helpful when one is attempting to identify project goals and specifications.) Von Fange (1959) suggests that one combine checklist ideas in an "idea matrix" in order to produce more concepts.

This is an excellent technique for generating ideas, either working by oneself or in a group.

Collective Notebook (CNB) Haefele (1962) originated this approach, in which every member of the group initially receives a notebook containing a problem statement and all preparative materials. Each member then records his/her thoughts and ideas about the problem during each day of a one-month period. At the end of this period, each person summarizes the 'best' ideas and other suggestions; the notebooks are then submitted to the group coordinator who then devotes his full-time attention to the contents of the notebooks and then generates a summary report. The group can then reassemble, if desired, for a discussion of the results.

This technique requires mutual cooperation, discipline, conscientious recording and effort. [For further information, see Gregory (1967) and Haefele (1962).]

Explain Difficulty Von Fange (1959) recommends that one attempt to explain his/her problem or difficulties to another person who is not very familiar with the project. The "communication challenge" with which the designer is then confronted helps him to more fully understand the problem and identify these difficulties. Ideas for possible solutions may also occur to him during this conversation with this "outside" person.

Forced Relationships Many of these techniques require that we "force" relationships or associations to occur between concepts, components, products or characteristics which are not normally related to one another. Whiting (1958) is credited with this approach of "free association" of ideas [see Osborn (1963)]. Parnes (1976) has suggested that one should use his imagination to take an imaginary "trip" (e.g., an ocean cruise, a Lunar flight) in order to generate ideas and forced relationships.

Example: Consider an automobile as a new product. Seemingly unrelated products, ideas or things include (a) houses, (b) horses, (c) farms, (d) birds, (e) chairs, (f) baby carriages, (g) paper, (h) earth and (i) plants. [Of course, the list of 'unrelated' items is endless.] We then can "force-fit" each of these items to our new product area.

(1) The automobile could serve as a dwelling (e.g., mobile home)
(2) We could increase the 'Horse'-power of the vehicle, use a horse to power the car or name the automobile after a horse (e.g. "Mustang'),
(3) The automobile could serve as a farming vehicle if we include attachments (plow, tiller, etc.),
(4) We could add 'wings' to the automobile's design for aesthetic purposes,
(5) The cushions of the car could be removable and use as portable chairs, etc.

Fresh Eye Approach In this technique, one seeks the (fresh) opinions of others who are not familiar with the particular problem or goal under consideration [Gregory (1967)]; the approach is similar to that entitled "Explain Difficulty" in its use of people external to the project.

Little Technique Developed at Arthur D. Little, Inc., this approach encourages the group to suggest as many ideas as possible without evaluation; because of this deferred judgment characteristics, it is very similar to brainstorming. However, in the Little technique, only the leader of the group knows the actual problem which is to be solved. As a result, the members avoid focusing upon "obvious" solutions too quickly (before they consider apparently unrelated ideas or concepts) [see Gregory (1967)].

Morphological Analysis In this technique, one analyzes the structure and characteristics of the problem, after which a force-fit is applied in order to develop relationships between these structural components. Ideas for accomplishing specific goals or for modifying system components can be generated and then combined in numerous combinations. This approach allows us to obtain a perspective of the organizational relationships between problem components; in addition, a matrix can be generated in order to establish relationships between individual components, goals and possible ideas/concepts. One can also apply computer analysis in order to create new combinations and relationships [see Allen (1962), Gregory (1967), Osborn (1963), Parnes (1976), Parnes, Noller and Biondi (1977) and Zwicky (1969)].

Finally, Allen (1962) created a device known as a "Morphologizer" in which individual sliding strips - upon which ideas and other information are written - may be moved relative to one another, thereby changing the relationships between these individual bits of informations.

Racking Technique Bits of information or ideas ("idea-bits") are recorded on small slips of paper, one idea-bit per slip; such bits of data as names, goals, words and phrases can be recorded. One then organizes these slips in rows and columns ('racks'). Finally, this information is manipulated in order to generate feasible ideas, concepts and design solutions.

This method provides us with a perspective of the available data and the ability to relate idea-bits. Processing of this data in creative ways can then be achieved more easily.

Ranking and classification of idea-bits can be effectively achieved on racking boards via the '7 x 7 technique' [see Gregory (1967)].

Rules 24, 25, 26 These rules are as follows [see Mudge (1971)]:

* Rule of 24: Be creative on a problem 24 hours per day (and record your thoughts).

* Rule of 25: A minimum of 2 ideas should be generated prior to analysis.

* Rule of 26: In order to generate at least 26 ideas, force yourself to think of at least one idea which begins with the letter A, one idea which begins with the letter B, etc., - until you have one idea for each letter of the alphabet [This is also known as Alphabetical Listing' - Hill (1983)]. A dictionary may aid the designer when using this approach.

Synectics - Developed by W.J.J. Gordon and others at Synectics, Inc., this approach emphasizes the value of analogies and metaphors in creative efforts.

The fundamental objectives about which the approach revolves are:

* MAKE THE STRANGE FAMILIAR -

One first analyzes the subject in order to identify problem components, their relationships and possible patterns. He then seeks analogies (or models) of the system in order to (a) increase his understanding of the problem and its goals, and (b) stimulate his creativity.

*MAKING THE FAMILIAR STRANGE -

In this case, analogies are developed in order to distort or modify a familiar object or product into a new design.

The steps of the process can be summarized as follows:

(1) PAG (Problem as Given) -

familiarize participants with the problem statement.

(2) Analysis/Explanation -

participants are given an explanation of the problem.

(3) Purge -

participants are allowed to suggest initial ideas for solving the problem; discussion then ensues in which the participants develop a fuller understanding of the problem.

(4) PAU (Problem as Understood)

each participant writes a restatement of the problem or identifies additional goals.

(5) EQ (Evocative Question) -

a question is asked which requires an analogical or metaphorical answer. Three distinct types of analogies may serve as answers to EQ's:

DIRECT ANALOGY: An actual comparison of similar events, processes or facts, e.g., the human eye may be compared to the lens of a camera.

PERSONAL ANALOGY: The designer attempts to imagine himself as the user/operator ('role playing') or as the product itself, e.g., the designer might imagine himself as the camera itself - trying to understand how he would feel (in a storage case, in use, in various temperature ranges and environments, etc.) and behave (he might seek to be lightweight, slim, invisible, etc.).

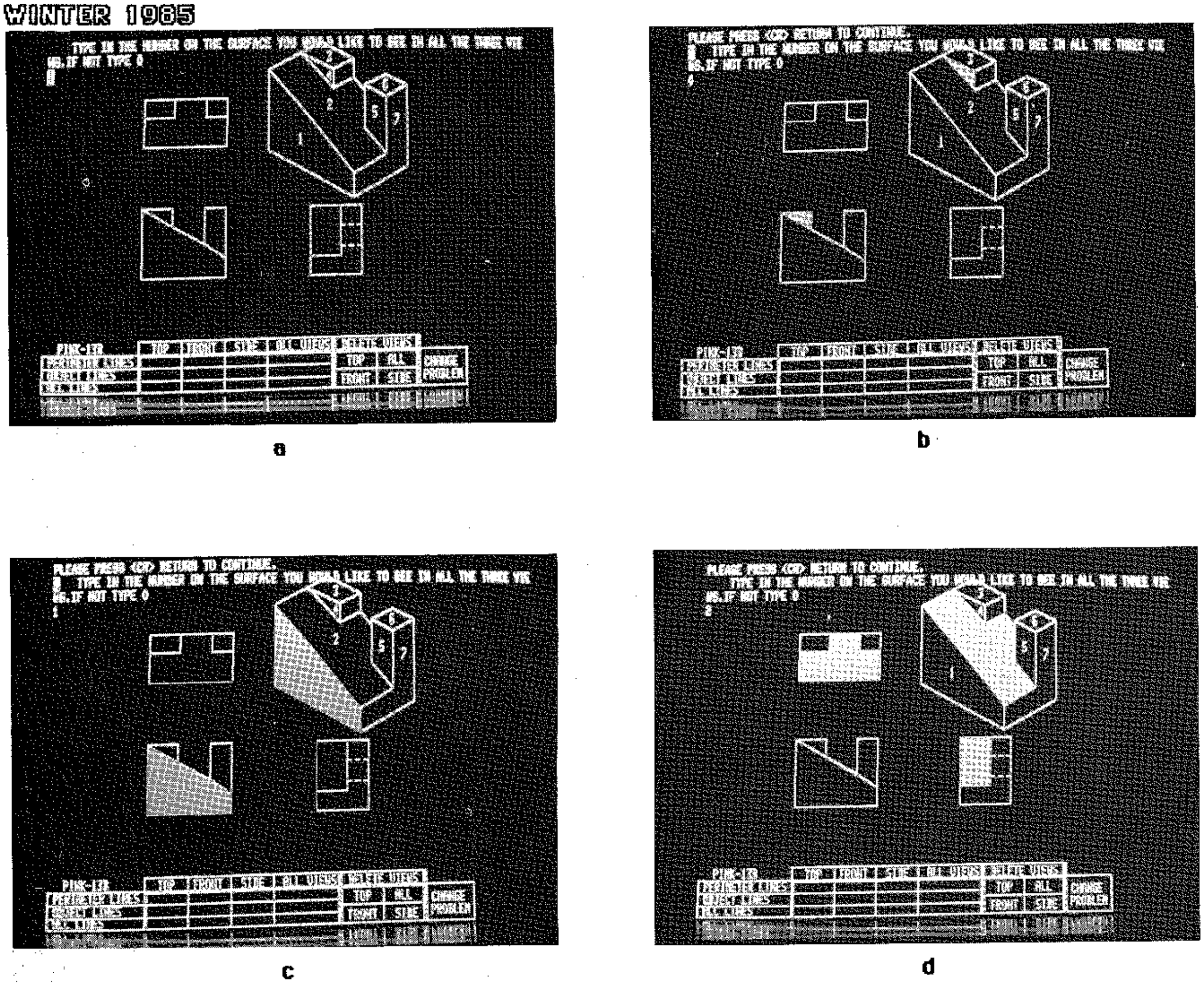



FIGURE 3

The tutor program was developed on a VAX 11/750 minicomputer and structured so that the student could use the program by simply typing the word **TUTOR**. An object could be selected by moving the cursor to an appropriate box, causing an isometric view to be displayed ( Figure 3a). Selecting a surface from the menu box would display the surface in all the views. This interactive approach made the program user-friendly, requiring almost no a priori computer knowledge. Prompts were brief and self explanatory, requiring no supervision in an open laboratory environment.

## Effect of Computer Program

Two classes of the introductory graphics courses were selected as the test population. Both sections were taught by the same instructor. Students were randomly assigned to the class by admissions and all exercises and delivery were kept the same for the two sections. Students in the experimental (computer) section were allowed to use the Tutor program. They could use the program as often as they wished but were required to turn in three computer exercises. The control group was not provided formal access to the Tutor program. There were 30 students in experimental and 23 students in control groups.

## Effect of Tactile Models

Two classes of the introductory graphics course were selected as the test population. Both sections were taught by the same instructor and students were assigned to the classes by admissions. Classroom instruction and exercises were the same for both classes other than the experimental (Goss Box) section. Students could handle the objects and use the Goss Box with no control other than a requirement of drawing one object on the glass box and viewing it Goss-style. There were 26 in the experimental and 23 in the control groups.

## Data Collection

A pretest was given to all sections on the first day of class. The post test was of two parts:

Part 1-multiview and isometric
Part 2-missing views and lines

The same tests were administered to all test classes and were graded by the same person. An attitude questionnaire was also administered in each class along with information regarding previous mechanical drawing and computer experience.

## ANALYSIS

Both pre and post tests were found to be positively skewed. Hence, it was decided to use differences between pre and post test scores as the dependent variable. A chi-square test revealed that the assumptions as to distribution of the scores were valid. Analysis of covariance was conducted with the pretest as a covariate. Previous experience of the test populations and some of the data:

| | no previous drawing |
|---|---|
| Control | 69% |
| Computer | 58% |
| Goss Box | 50% |

| | no previous computer |
|---|---|
| Control | 39% |
| Computer | 31% |
| Goss Box | 23% |

| | pretest means |
|---|---|
| Control | 86.56 |
| Computer | 84.26 |
| Goss Box | 84.42 |

| | pretest-post test 1 gain |
|---|---|
| Control | +6.46 (SD=13.51) |
| Computer | +11.67 (SD=14.74) |
| Goss Box | +10.92 (SD=17.67) |

| | pretest-post test 2 gain |
|---|---|
| Control | -10.33 (SD=17.32) |
| Computer | -11.60 (SD=22.21) |
| Goss Box | -9.53 (SD=16.59) |

Analysis of covariance showed that on adjusted scores it made no difference on post test 1 whether students had previous mechanical drawing experience ($p>.5$, $F=0.33$) or computer experience ($p>.3$, $F=1.07$). For post test 2, neither previous drawing, nor computer experiencee had a significant effect ( $p>.1$, $F=2.02$;$p>.9$, $F=0.01$)

The mean gain in post test 1 by the computer group was 5.21 points higher than the control groups whereas those of the Goss group were 4.46 points higher. However, an F of . 82(p..2) suggests that the difference was not significant at this level. Post test 2 gain for the computer group was 1.27 points lower than the control group and 0.8 point higher than the Goss Box group. But again, an F of 0.17 ($p>.8$) suggests this difference to be non-significant.

## DISCUSSION

The results of the analysis of covariance indicate that the computer group showed the greatest gain (11.67) in the pictorial and three-view concepts. The Goss group showed a gain of 10.92 while the controls registered a gain of 6.42, despite a higher pretest score. On concepts involving missing lines and views, the Goss group did better than the computers but still worse than the control group. This may be due to humans learning three-dimensional skills more efficiently from three-dimensional information. The additional sense of touch may also provide additional information.

Two frogs fell into a deep cream bowl

The first one was an optimistic frog

The second one took a gloomier view

"We shall drown," he cried, "We're through."

So with a last despairing cry

He flung up his legs and he said, "Goodbye."

Quoteth the other with a determined grin

"I can't get out but I won't give in.

I'll just swim around till my strength is spent

Then I'll die all the more content."

Bravely he swam till it was seen

The struggles began to churn to cream

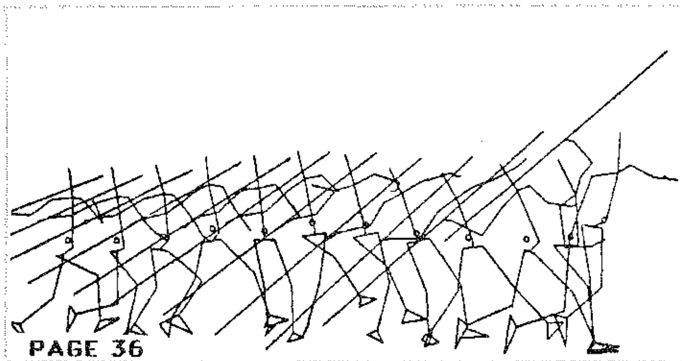
And on top of the butter at last he stopped

And out of the bowl he gaily hopped.

What is the moral? It's easily found.

If you can't hop out, keep swimming around.

~Unknown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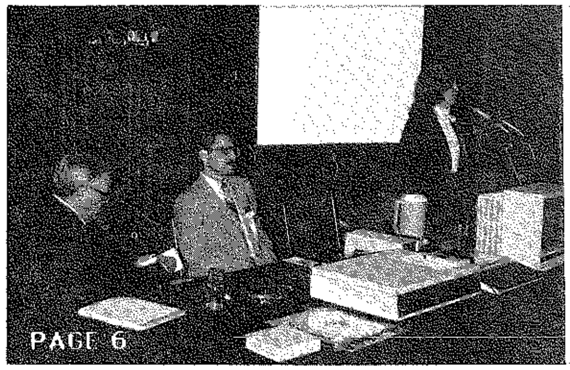
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