

# **Future Directions for Graphics: A Look at the New Technical Graphics Curriculum in NC High Schools**

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## **Abstract**

In 1996, a committee of North Carolina high school technical graphics teachers, led by Tom Shown of the State Department for Public Instruction, and with advice from the first two authors, produced a revised technical graphics curriculum for the State of North Carolina. This new curriculum reflects changes the field of technical graphics over the last 15 years and includes material on solids modeling, animation and rendering, geometric dimensioning and tolerancing, and scientific visualization. The goal of the new curriculum is to both provide up-to-date vocational skills to students at the high school level, but also to improve the academic content of the graphics curriculum. The scientific visualization component is perhaps the most progressive component of this curriculum revision in that it promotes cross-disciplinary course development between the technical graphics (a vocational area) and science (an academic area) curriculums. With this collaboration, both the students and teachers learn how graphics can be used to enhance understanding of technical and scientific concepts. This paper outlines the structure of the new curriculum and its potential impact on teaching graphics at both the two-year and four-year college level.

## **Introduction**

To this date the North Carolina Department of Education has supported curriculum for traditional drafting programs in the state's high schools. These programs have for the most part prepared students for the areas of engineering and architectural graphics. Students continuing on this career path either became architects, engineers, or drafting technicians in these or related areas. While contemporary high school drafting (engineering graphics) programs now use sophisticated graphic tools to create 2-D and 3-D wire frame and solid models, their focus has remained narrow. It is now apparent that changes primarily brought about by advances in technology have created new opportunities to use similar tools to promote and enhance the study of the physical and social sciences, including mathematics (Figure 1).

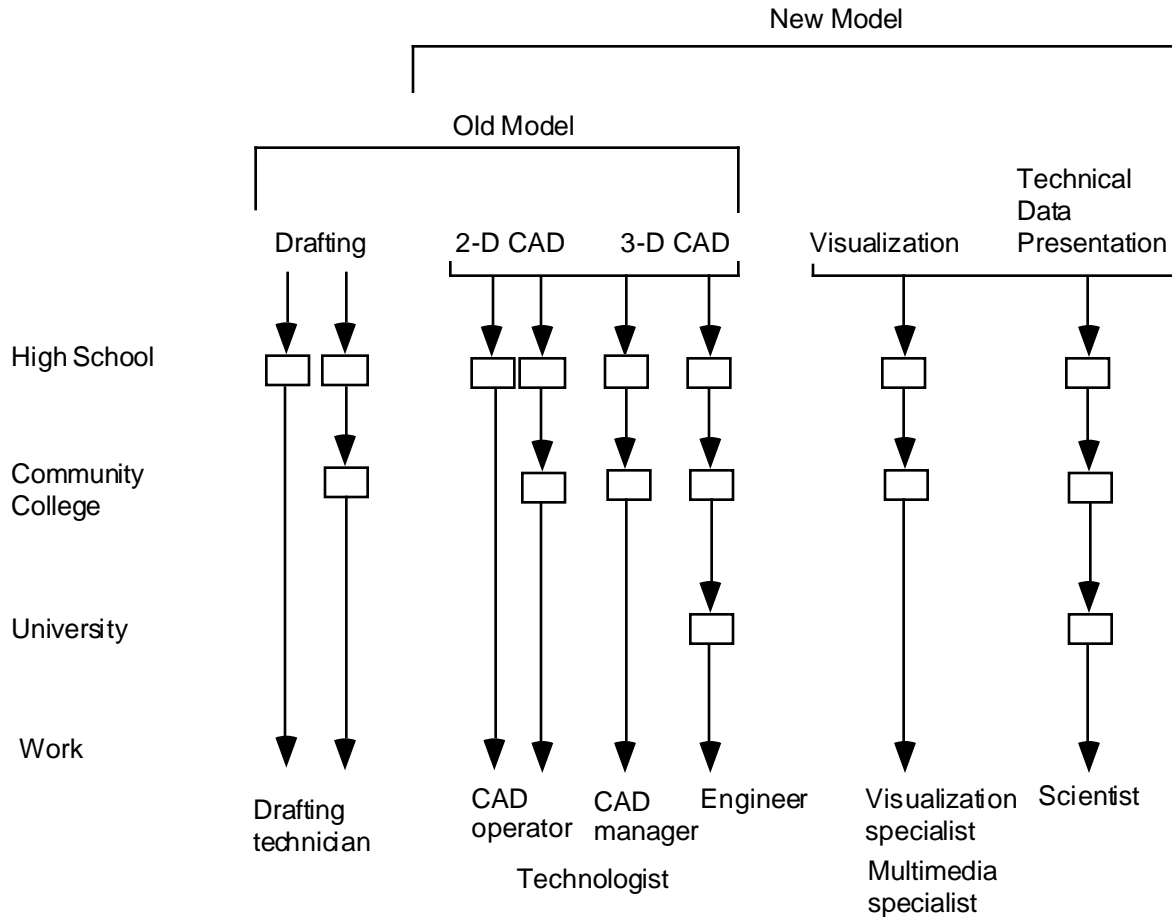


Figure 1. Old and new models for technical graphics education

Most of those aware of this emerging technology accept the premise that graphic tools can and should be used to better understand abstract and numerical concepts. Simple and sophisticated graphic tools are used in the sciences, business and industry, finance, higher education and virtually all major areas of our economy.

Presently the North Carolina University System offers programs in computer graphics, mathematics, and other related areas such as engineering, computer science, operations research, and management information systems. All of these programs use advanced graphic techniques as part of their curriculums. Wake Technical Community College offers a curriculum in *Scientific Visualization and Computer Graphics Technology*. However, there is no secondary program designed to prepare students for apprenticeship programs, community college and /or university programs for the rapidly expanding occupational opportunities of scientific and technical visualization.

Cognizant of the above concerns, representatives from MCNC (Microelectronics Center of North Carolina); NC State University Department of Math, Science, and Technology Education, Department of Marine, Earth, and Atmospheric Sciences; Wake Technical Community College Engineering Technology Division; as well as the NC Department of Public Instruction math, science, instructional technology, and technology education divisions sought ways in which

to build a strong secondary program in Scientific and Technical Visualization, focusing on the use of sophisticated graphics tools for the purpose of studying math and sciences. Members sought and received funding through a Federal Tech Prep Project and are now in the process of developing a new visualization curriculum. This project will attempt to develop an exemplary Tech Prep 2+2+2 program which will: 1) train select teacher teams (one science or math teacher collaborating with one engineering graphics or technology teacher per team) in the use of visualization software applied to the study of sciences or mathematics, 2) develop a state-of-the-art Scientific and Technical Visualization curriculum, 3) provide teachers with contemporary hardware and software, and 4) develop a management team and curriculum advisory board to direct the project and oversee the development of the curriculum. This team and advisory board will be comprised of high school, community college, and university teachers, and representatives from the information technology industry.

With the implementation of this grant and development of the curriculum, students will be able to use scientific and technical visualization tools to better understand complex subjects and, as importantly, be able to use these same tools in the workplace.

### **A New Course Needed for Drafting and Scientific Visualization**

The starting point for the development of a scientific and technical visualization curriculum was an introductory course that met the basic requirements of all students needing to understand visual communications. The curriculum committee for this new course, comprising of high school technical graphics teachers, with input from community college representatives and four-year university personal, felt that the new fundamentals course needed to be developed for all students, academic and vocational bound. The curriculum committee strongly believed that a high school student, whether he or she decides to go to the workplace upon graduation, take classes at the local community college, or attend a four-year university, a good foundation in visual science is needed for a successful career in any profession the student may chose as a career.

The course needed to meet the basic requirements for the traditional mechanical and architectural specializations a student could take upon completion of this course, as well as those who may want to look at the broader scope of scientific and technical visualization (Figure 2). The sequence for students wanting to take one of the advanced course offerings would begin with the new course, titled: *Drafting and Scientific Visualization*.

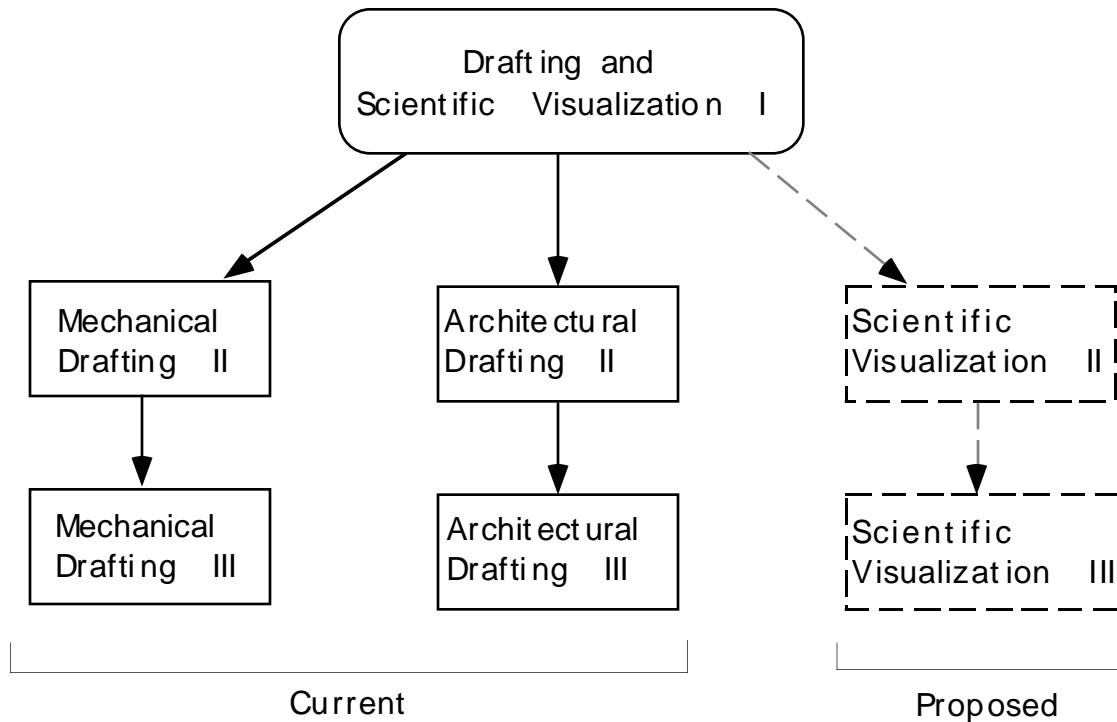


Figure 2. High School Technical Graphics Course Sequence

### Course Description

This first initial course in visualization introduces students to the use of simple and complex graphic tools used to communicate and understand ideas and concepts found in the areas of architecture, manufacturing, engineering, science, mathematics, and other related areas. Topics include problem-solving strategies, classical representation methods such as sketching, and geometric construction techniques, as well as computer assisted design and drafting. (A complete outline of the course is provided in Appendix A). Projection methods incorporated into the course include both orthographic and pictorial projection techniques. Skills student would obtain through this course include graphical forms of communication, math, science, leadership, and problem-solving strategies. Work-based learning was integrated into the course through the use of field trips and job shadowing.

The curriculum committee developed this new introductory course in visualization to be demanding on the student; requiring the application of complex math and science concepts for the design and construction of virtual and physical models used in science, mathematics, manufacturing, and structural systems. Though requiring a high degree of learning, this exciting course afforded students the opportunity to use both creativity and personal freedom.

The curriculum framework developed for this course helps teachers offer a focused, demanding, and engaging course that addresses the essential core concepts and principles of technical graphics and scientific visualization. The curriculum framework includes specific learning objectives, evaluation strategies, recommended activities, a listing of equipment and supply needs, and reference materials.

This course may be taught using individualized instruction, whole class, or a combination of instructional strategies. Total time needed for completion of the objectives and competencies for the course is 135-180 instructional hours. The

course objectives are to be taught concurrently within the larger context of activity based instruction. This allows for the efficient use of time and is good pedagogy. Regardless of the instructional methodology used in the course, it is essential that the activities reflect the competencies and objectives of the course.

#### Course Outline

The course has seven main competency areas that include leadership development, design and problem solving, basic drawing skills, geometric construction, orthographic projection, pictorials, and computer-aided drafting. Each competency area was developed for the benefit of the student and their basic need for fundamental understanding of both visualization and leadership skills needed in the workforce.

Leadership development was included in the curriculum to develop the student's speaking, career development, and business meeting skills. Areas of instruction for this competency include parliamentary procedure, establishing short and long term goals, and help identify career goals and opportunities. The design and problem-solving competency helps students understand the need for and apply problem-solving principles to design concepts as used in visualization. Students are to apply these techniques throughout the course. Basic drawing skills competency allows the student to demonstrate and interpret basic drawing concepts and apply drafting and designing techniques. This includes the use of equipment, sketching practices, and basic hand lettering techniques. The competency for geometric construction is to teach the students to interpret and apply geometric construction techniques and principles. This includes defining geometric shapes and terms, as well as demonstrate basic geometric construction practices. Orthographic projection techniques and principles are also a major competency students must develop in this course. This competency includes areas of defining and explaining principles of orthographic projection and developing the skill to draw these projections. Pictorials are covered in this course through the basic understanding of both isometric and oblique pictorial drawings. Students are to develop the capability to identify, explain the concepts and principles used in executing both an isometric and oblique drawing. A demonstration of skill at sketching and drawing both of these pictorial draws are included in the course.

Once the above competencies are covered by the teacher, the student is to apply these competencies to computer-aided drafting (CAD). This final competency is to explain and apply the concepts and principles of CAD. Students are to identify and explain basic CAD terms, commands, and operations used to create a simple line drawing. A final objective of this competency is to produce a CAD drawing.

#### Completion of the Course

Once students have completed all of the competencies in a satisfactory matter, they can continue their drafting and visualization skills in more advanced courses offered in the state's curriculum. Students will have the fundamental knowledge to peruse either the mechanical or architectural graphics area, or study a more broader approach to graphics by studying scientific visualization. Other students may stop at this point in the study of visualization, either way, students now have a fundamental foundation in visualization that will aid them the rest of their lives no matter what career field they choose to go into upon graduation.

### **Integration of Graphics in the Curriculum**

The introductory course, Drafting and Scientific Visualization I, attempts to both reacquaint students to their innate ability to view the world around them and begin to introduce them to broadly applicable graphics techniques. Through the introduction of projection techniques, students develop their abilities to visualize three-dimensional form and to represent them as two-dimensional projections. Exposure to basic graphic production tools — whether they be mechanical or computer based — and fundamental graphic elements precedes the introduction of projection techniques and gives students a vehicle to create the projections. These projections also gives students a first look at the more formal conventions of technical graphics, such as the use of hidden and center lines, and the placement of views. This foundation now leads, as previously outlined, to three possible paths which the student can take: Architectural, Mechanical, and Scientific. In all three of these paths, fundamental visualization skills and basic technical graphic communication continue to be reinforced, but the vehicle becomes more specialized applications specific to the three sub-disciplines.

Architectural and mechanical graphics are the two areas of technical graphics typically taught at the high school level. Vocational training in architectural graphics prepares students for work in the A/E/C (Architectural/Engineering/Construction) industry, while mechanical graphics training prepares students for manufacturing industries. Scientific visualization (or scientific graphics) is a newer area which does not have as clearly a defined vocational or academic goal. Unlike the other two areas, scientific visualization does not focus on the production of graphics directly involved in the construction or manufacture of tangible products. Instead, its focus is to use graphics to communicate and facilitate more abstract problem-solving and analysis.

### **The Scientific Visualization Course Sequence**

Like architectural and mechanical graphics, scientific visualization may be used to represent a physical object, but that object may be as small as a molecule or as large as a solar system. In addition, scientific visualization may be used to represent more abstract *systems*. A system represents a physical or abstract model which contains a series of interrelating elements. The goal, typically, will be to design an experiment in which the system is *probed* and the system's responses are *recorded*. To bring this description back to earth, an example might be setting up an experiment to better understand an industrial boiler, the system. The boiler is probed by applying heat to it and its response is measured by recording its pressure at various temperatures. A traditional mechanical drawing could be made of this boiler, and though these drawings could be useful in the construction of it, it would not very helpful in understanding how the boiler functioned as a system. On the other hand, a graph could be created of the relationship between temperature and pressure. In addition, a three-dimensional model of the system could be constructed and the effects of internal pressure on the boiler walls could be simulated and represented as rendered pictorials. In addition, an interactive, dynamic multimedia presentation could be created as a teaching tool to demonstrate the basic physical principles represented by this system. All of these graphical representations are examples of how scientific visualization is used to explore systems.

Unlike the architectural and mechanical tracks, the scientific visualization

track is not likely to prepare students for a vocation directly out of high school. Instead, this track is likely to prepare for a program directly related to scientific visualization at the community college level or enrichment for a scientific or technical career in areas such as engineering, medicine, or the physical sciences. Therefore, the students who are likely to be attracted to this course sequence are ones who are largely on an academic track and may never have taken a vocational course before. The conceptual basis of scientific visualization makes well suited for cross-disciplinary activities with traditional academic tracks such as chemistry, earth sciences, and physics. In addition, schools with pre-engineering programs will also have other courses which will mesh well with the scientific visualization sequence.

The second and third level scientific visualization courses are envisioned to cover a range topics which give students exposure to all of the major conceptual areas of what is commonly understood to be scientific visualization and experience in a broad range of graphic techniques (Figure 3). Unlike many of the graphic techniques covered in the architectural and mechanical areas, the techniques in the scientific visualization area are more broadly applicable. On the other hand, reflecting the more academic leanings of this track, the theoretical and operational basis as to why particular graphic techniques are used are covered in more depth. In outline, the primary areas covered in the second and third level courses are as follows:

- Introduction to scientific visualization
- Graphing/Plotting
- Image Processing
- Animation and Simulation
- Presentation and publication

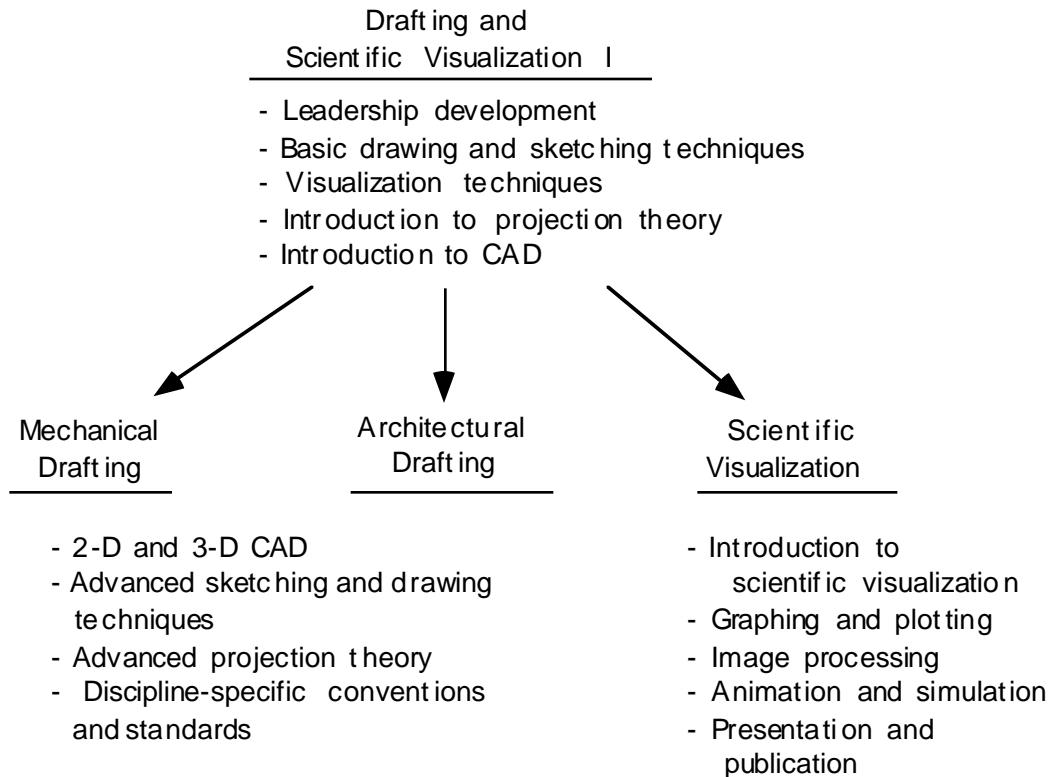


Figure 3 - Comparison of course content for three tracks

### Introduction to scientific visualization

This area places scientific visualization in context with other technical graphic communication methods. The concept of the exploration of systems is introduced along with a review of the general types of systems which might be explored, analyzed, and presented using scientific visualization techniques. A foundation is built around an understanding of the different types of data variables which may be used to describe both the probing and recording techniques used on the system.

### Graphing/Plotting

A taxonomy is presented which classifies the visualization method used based on both the types of data variables which are used and the intended audience of the visualization. In addition, the basic graphic elements used in graphing plotting are introduced along with a review of two-dimensional coordinate systems used for organizing the graphic elements. Graphing and plotting exercises are done based on a number of different application areas. In some cases, the data can be collected from experiments the students create themselves. In other cases, the data may be gathered from both from print and electronic (e.g. Internet) sources. The primary focus in this section will be 2-D graphing/plotting methods, done both by hand and using computer-based tools.

### Image Processing

This area focuses on area rendering techniques using image processing techniques. Coupled with this section is an introduction to color theory: both its perceptual basis and computer-based generation methods. Through the use of image processing software, the basic principles of how such software is designed and

functions is explored. Image processing exercises are based around data gathered from published sources, both from images created by the students (either using all digital or a combination of photographic and digital methods) and with images acquired through the Internet. Throughout this section techniques used by professions which rely on image processing techniques (i.e. medical and earth sciences) are examined.

#### Animation and Simulation

Two major new areas are introduced in this area: dynamic visualization and 3-D modeling techniques. Dynamic visualization through animation and simulation is shown how the change in a system over time or as a realtime response to user input can be represented. 2-D simulation is explored using software tools modeling either physical (e.g. kinematics/dynamics) or theoretical (e.g. ecological models) systems. Similarly, 3-D modeling tools can be used to create representations of systems which can then be manipulated to represent some process. Using these software tools, animations are created to represent a dynamic process. Coupled with the creation of animations from 3-D models is an introduction to rendering techniques, including proper use of lighting, color, and camera position.

#### Presentation and publication

This last area focuses on the integration of information used to represent and analyze a system into a form which can be presented to an audience. Information sources include textual and numeric data in addition to the graphics created as part of the visualization. The focus will be on the clear and concise presentation of necessary information to the intended audience. Exercises will use multimedia presentation software which allows the integration of both static and dynamic graphics. This last area can be used as part of a capstone project encompassing both the scientific visualization course and other related courses.

### **Impact on the College-level Technical Graphic Curriculum**

Technical graphics at the College/University level has been in a long term decline in part because of a shift in engineering curriculums away from hands-on practical skills and towards a science/theoretical basis. The argument has been given that these types of courses are more appropriately taught at two-year and technical colleges and not at research-oriented universities. This reality runs counter to a number of important points:

- Engineers taught at universities still need hands-on experience and instruction with the tools they will be using in their professional careers, including technical graphics tools.
- Technical graphics is not simply a vocational skill, but contains a challenging theoretical foundation worthy of being taught at all levels of academia.
- Advanced computing technologies have only increased the importance of graphics as a means of communication, yet technical graphics courses (if any are required) are often the only place students get any formal instruction in developing their ability to effectively use graphics.

A scientific visualization curriculum at the high school level addresses these issues in a number of important ways. First, as previously mentioned, this curriculum has the potential of attracting academic track students who otherwise might not consider taking courses from a vocational department. Exposure at the high school level to the importance of graphics in academic disciplines can only help

counter trends at the college/university level which tend to steer students away from graphics. Secondly, students are exposed to a much broader use of graphics in scientific disciplines. Specifically, students are given instruction in the use of the types of graphics they are likely to use much more often in their academic courses. Whereas architectural graphics may never be used by students in college and mechanical graphics may only be used by a few engineers in design courses, scientific visualization can be used in scientific and technical courses throughout a student's four years of post-secondary education. Finally, and most importantly, scientific visualization adds substantially to the foundation of graphics as a discipline, not simply a vocation. The scientific visualization curriculum is very clearly built from a conceptual and theoretical foundation based on geometry, mathematics, and psychology. At the same time, its operational functionality can easily be demonstrated, allowing students to ground its principles in real world applications.

### **Conclusion**

This new technical graphics curriculum project is currently being designed to prepare students for the rapidly expanding scientific and technical visualization computer graphics industry through the integration of math, science and computer graphics technology. A model to be used in implementing this project will be a 2+2+2 Tech-Prep program centered through the community college system, but with support from universities, state department personnel, and secondary school systems. The project is to be directed by teachers from the disciplines of physical and mathematical sciences and computer graphics technology, as well as representatives from business and industry. The overall outcomes for the project is to prepare students to enter computer graphics industry as well as being skilled for other occupations that use complex graphic tools. This multi-disciplinary approach will enhance student learning and develop skills to be used in fields of engineering, technology, math, science, and computer graphics industries.

The next step for the new technical graphics curriculum was to receive funding for the development and implementation of the program. A grant was obtained to accomplish these goals and objectives for the curriculum project through the Tech-Prep Program. Financial support was received for the following areas: workshops and training; curriculum development and writing; consultants and specialists; and, related equipment. This funding is just a start in developing the needed materials and resources to complete the project. The future of program will be to implement these materials and resources and being the assessment component of the project for new instructional strategies and ideas that can be used with this curriculum for an ever changing technological world.