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Regis University
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THE ROLE OF ENGINEERING GRAPHICS IN THE
CIVIL ENGINEERING TECHNOLOGY CURRICULUM

by

Charles F. DiDomenico

A Research Project Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Education

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ABSTRACT

The Role of Engineering Graphics in the Civil Engineering Technology Curriculum

This author presents the concept that the basic mechanical drawing course at Pueblo Community College is no longer relevant to the graphics skills required in industry and should not be a prerequisite in the civil engineering technology curriculum. A review of literature reveals that basic mechanical drawing courses are not routinely integrated into civil engineering technology programs in the Colorado Community College System. The literature shows that the majority of programs in the community college system utilize computer aided drafting as the prerequisite. Alternatively, as a replacement, the author presents a hybrid mechanical drawing-computer aided drafting (CAD) curriculum that integrates scaling, geometric sketching, and spatial relationships. The curriculum is supported with the use of on-line lecture material and training modules.

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Chapter 1

INTRODUCTION

Engineering educators are continually challenged by the need to keep their curricula relevant and current with the populations they serve. The ability to communicate across a broad spectrum of interests is a vital component, not only in education, but also in industry. Effective communication is a lifelong skill.

The ability to communicate effectively in engineering goes beyond written and verbal expressions; it includes the ability to communicate graphically with the use of computer aided drafting (CAD) software. The integration of graphics communication into the engineering curriculum is vital because of its importance across the curriculum and because of its relevancy to modern engineering practices.

Statement of the Problem

The prerequisite for half of the freshmen level courses in the Civil Engineering Technology (CET) Associate Degree program at Pueblo Community College (PCC; 2009) is ENT 131-Mechanical Drawing 1 (ENT 131). However, the instructional material covered in this course, for the most part, is no longer relevant to the engineering graphics skills required in industry. Therefore, ENT 131 should no longer be a course in the CET curriculum, and a hybrid mechanical drawing-computer aided drafting (CAD) course should be developed as a replacement.

Background of the Problem

Humans have used drawings to represent design concepts since the beginning of recorded history (Giesecke, Mitchell, Spencer, Hill, & Loving, 1975). As a previous instructor for ENT 131, this author notes that the basic drafting procedure utilized is to affix a piece of paper, or other material, on a drafting table and utilize a sliding straightedge ruler in combination with various tools, such as a triangle and a pencil, to produce the technical drawing. Technical drawings produced in ENT 131 relate entirely to the mechanical engineering field with no work completed in the civil engineering discipline. All associated lettering and dimensioning is accomplished by hand. A notable portion of the course is devoted to quality in lettering and line work through repetitious hand drawings. The remaining time is devoted to relevant skill building concepts such as learning how to use the engineer's and architect's scale, geometric construction and spatial imagination skills, such as perception of edges, planes, spaces, and relationships between objects (Colorado Community College System, n.d.). Also, these skills are crucial components for creating computer-generated drawings in engineering. The primary difference between the two drawing methods is that the student who uses CAD can focus on acquisition of the relevant skill and not the labor of hand drawing.

Drafting tables have been replaced by CAD workstations in industry. In the author's 25 year professional engineering career, manual drafting procedures were used in only the first 5 years. Henceforth, CAD was the industry standard. The student's investment in hand drawing, lettering, and dimensioning has no market value in the industry. As such, the course is not relevant in the civil engineering market.

As a prerequisite to other courses within the CET program that this author instructs, ENT 131 has little value. For example, as a prerequisite to courses such as Survey Drafting, Structural Detailing, and Residential Architecture, the students in these courses perform the work with the use of CAD, with no hand drawing, lettering, nor dimensioning required or performed.

Purpose of the Project

The purpose of the project was to design a course that will take the important skill building concepts of scaling, geometric construction, and spatial imagination from ENT 131 and integrate them into an existing CAD course; thereby, a hybrid mechanical drawing-computer aided drafting course will be developed. The objective is to provide the student with a course that is relevant in academia and industry.

Chapter Summary

Relevant coursework within a program of study is vital to the recruitment, retention, and success of its students. It is this author's belief that a notable portion of ENT 131-Mechanical Drafting 1 is not relevant to the CET program, and a new hybrid course should be developed.

In Chapter 2, the Review of Literature, this author provides the background material in support of the project purpose. This author: (a) examines the occurrence of ENT 131-Mechanical Drawing 1 in Colorado Community College System (CCCS) programs, (b) provides an historical perspective on technical illustration, and (c) analyzes the role of visualization skills and spatial reasoning in engineering graphics.

Chapter 2

REVIEW OF LITERATURE

The purpose of the project was to develop a hybrid course that integrates the important skill building concepts of scaling, geometric construction, and spatial imagination from ENT 131-Mechanical Drawing 1 (ENT 131) into an existing computer aided drafting (CAD) course at Pueblo Community College (PCC). The project is supported by the literature review, which provides an overview of the findings on the integration of ENT 131 into civil engineering technology programs in the Colorado Community Colleges System (CCCS). Secondly, trends are identified in the use of computer aided drafting (CAD) courses as a requisite to engineering or related courses in the same data set. Also, an historical perspective on engineering graphics is reviewed, including the necessary skills of: (a) visualization, (b) sketching, (c) geometric construction, and (d) scaling.

Colorado Community Colleges

The CCCS (2008) is the governing body for the 13 community colleges in the state. The system serves more than 107,000 students annually and is the largest system of education in Colorado.

In an effort to facilitate transfer, articulation, and curriculum quality across secondary and community college structures, the members of the CCCS (2008) developed a common course numbering format. Courses with common content carry the same prefix, number, title, credits, description, competencies and outline. As such,

essentially, the course, ENT 131, will employ the same course content throughout the colleges in the system. The use of common course numbering provides the basis for the comparison of engineering graphics and CAD courses across the system.

ENT 131 System Prevalence

This author believes that the prevalence of ENT 131 in community college programs is an indicator of its relevancy in the system. According to this metric, it is assumed that a widespread occurrence of ENT 131 in the system indicates that the course is relevant in academia and industry. Conversely, no occurrences or a low number of occurrences may indicate that the course is no longer relevant. The most current catalogs from the 12 comparison colleges in the system were reviewed, and the occurrence of ENT 131 in the various programs and curriculums is tabulated in Table 1.

Two tabulated results merit further review: (a) Colorado Northwestern Community College (CNCC; 2008), and (b) Front Range Community College (FRCC; 2008). At CNCC, an associate's degree in Civil Engineering Technology is offered. The CNCC program includes courses in the following common course numbering format prefix areas: (a) computer aided drafting (CAD), (b) engineering (EGG), (c) engineering technology (ENT), (d) architectural engineering and construction management (AEC), (e) geographic information systems (GIS), and (f) technical (TEC). At CNCC, ENT 131 is not offered, instead, EGG 101-Engineering Graphics (EGG 101) is offered as a prerequisite to CAD. In the CCCS (2008), EGG-101 is described as a course that provides an application of engineering graphics as a communication form and a tool to solve three-dimensional design problems. The topics include: (a) orthographic, axonometric, and isometric projections; (b) sections and auxiliary views; and (c) the

Table 1

Prevalence of ENT 131 in the Colorado Community College System

Community College ^a	CET ^b	Related Programs Offered ^c	ENT 131 ^d	CAD as a Requisite ^e
Arapahoe (2008)	No	Engineering Technology	No	Yes
Aurora (2008)	No	None	No	N/A
Colorado Northwestern (2008)	Yes	N/A	No	No
Denver (2008)	No	Engineering Graphics	No	Yes
Front Range (2008)	No	CADD	Yes	Yes
Lamar (2009)	No	None	No	N/A
Morgan (2008)	No	Construction Technology	No	Yes
Northeastern (2008)	No	Pre-Engr & Landscape Tech	No	Yes
Otero (2009)	No	Pre-Engineering	No	N/A
Pikes Peak (2009)	No	Architecture & Construction Tech	No	Yes
Red Rocks (2008)	No	Engineering Graphics	No	Yes
Trinidad State (2008)	No	None	No	N/A

^a Colorado Community College System. ^b Civil Engineering Technology program available at community college. ^c Community college offers a related technical program. ^d ENT 131 course available at community college. ^e CAD a pre-requisite or co-requisite to the CET or related program.

geometry of lines, planes, and curved surfaces. This course is an introduction to PC-based, menu driven, 3D computer aided design systems, spreadsheets, and freehand drawing.

As a basis for comparison, CCCS (2008) describes ENT 131 as a course that enables students to achieve the following standard competencies: (a) proper care and use of drafting equipment, (b) draw basic mechanical parts with use of an orthographic projection, (c) draw basic isometric drawings, (d) draw basic sections drawings, (e) use basic dimensioning techniques, and (f) produce auxiliary views of mechanical parts. Similarly, CCCS describes the basic computer aided drafting course (CAD 101) as a course that enables the student to: (a) demonstrate file management, (b) apply the Cartesian coordinate system, (c) develop drawing set-ups, (d) use drawing aids, (e) apply layer usage, (f) construct geometric shapes, (g) edit objects, and (h) perform arrays.

The program at FRCC (2008) does not offer an associate's degree in Civil Engineering Technology, but it does offer an associate's degree in Computer Aided Drafting and Design. The Computer Aided Drafting and Design degree includes courses in the following prefix areas: (a) computer aided drafting (CAD), (b) architectural engineering and construction management (AEC), and (c) engineering technology (ENT). The course, ENT 131, is a corequisite to the CAD courses.

The tabulated results in Table 1 confirm the low prevalence of ENT 131 in curricula throughout the system. Also, in programs that offer CET or related programs, CAD is the prerequisite or foundational course in the program, not ENT 131. This author believes that this is an indicator that ENT 131 is no longer relevant in the CET program at PCC.

Engineering Graphics: A Common Language

The old Chinese saying, “one picture is worth a thousand words,” is foundational to graphics communication. In a world where there are more than 6,809 distinct languages (Anderson, 2004), the language of graphics, or drawing, has been the universal language since the earliest times. Even highly developed word languages are inadequate to describe the size, shape, texture and relationship of physical objects. For every manufactured object, there are drawings that describe its physical shape and size completely and accurately; thereby, engineering concepts are communicated for the purpose of manufacturing or construction (Jensen, Helsel, & Short, 2008).

Hieroglyphics was one of the earliest forms of communication, and it utilized pictographic scripts to communicate (Giesecke, Mitchell, Spencer, Hill, & Loving, 1975). These forms of graphics communication became the abstract symbols used in writing today. Thus, even the letter characters used today have their basis in drawings.

The Evolution of Engineering Graphics

Graphics have developed along two definitive lines: (a) artistic and (b) technical (Jensen et al., 2008). Artistically, drawings were used to express aesthetic, philosophic, or abstract ideas. Technically, drawings were used to convey design ideas and intent. Engineers have always needed a technique to create and communicate their design ideas (Barr & Juricic, 1994). Barr and Juricic noted that one of the earliest known engineering drawings was the design of a temple fortress engraved upon a stone tablet by the Chaldean engineer Gudea in about 2130 B.C. The stone tablet included a pictorial stylus and a notched bar that resembled a scale (see Figure 1).

Figure 1. Chaldea statue.¹

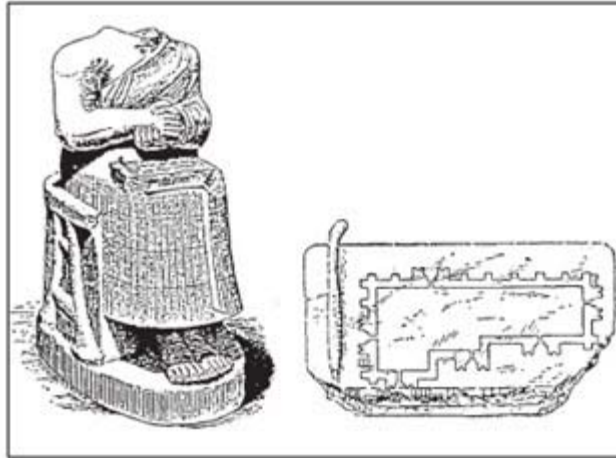


Figure 1. The headless statue of Gudea, an Engineer-ruler of Chaldea (Babylonia). Inscription on the skirt relates to the design, building, and dedication of the temple of Ningirsu. A plan view of the stone tablet visible on the lap of the statue, including the stylus and the scale with which the drawing was done is shown to the right of the statue.

¹From “*From Drafting to Modern Design Representation: The Evolution of Engineering Design Graphics*,” by R.E. Barr and D. Juricic, 1994, *Journal of Engineering Education*, 83, p. 264.

The Egyptian era provided the concept of an engineered drawing based upon a grid system. Barr and Juricic (1994) referenced a drawing made on papyrus of a portable Egyptian shrine around 1500 B.C. They indicated that no straightedges were used in the drawing of the shrine, but the background of the drawing has a red grid of straight lines made by touching the papyrus with a tight string dipped in red pigment. The shrine was then drawn in reference to the grid lines (see Figure 2).

Vitruvius (2003), a Roman architect and engineer in 30 B.C., reported that an architect of his time must be skillful with a pencil, rule, and compass so that drawings could be used to communicate the intent of the work proposed for construction. Also, Vitruvius noted that geometry was needed to understand the use of the rule and compass in making plans for buildings.

Figure 2. Egyption shrine.²

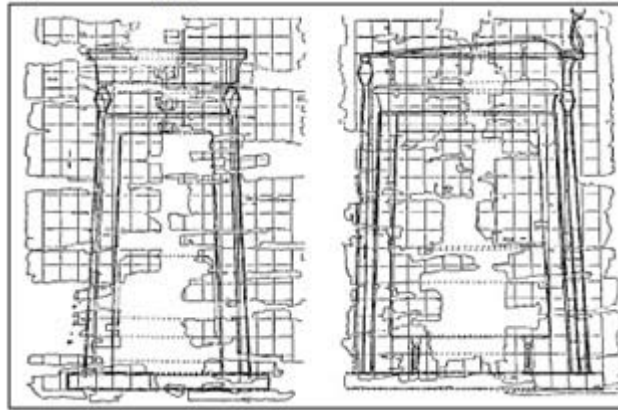


Figure 2. Papyrus remnants shown in this figure are from Egyptian times, dated about 1500 B.C. It seems to represent a portable Egyptian shrine shown in two orthographic views. It is not clear whether the views have been properly aligned. No straightedges were used, but the drawing background has a red grid of straight lines made by touching the papyrus with a tight string dipped in red pigment. The black outline lines of the object were then made with reference to the grid lines.

²From “*From Drafting to Modern Design Representation: The Evolution of Engineering Design Graphics*,” by R.E. Barr and D. Juricic, 1994, *Journal of Engineering Education*, 83, p. 264.

Prior to the early part of the 15th Century, technical drawings conveyed plan view information with unrelated elevation drawings (Barr & Juricic, 1994). Plan view drawings are graphical representations of an object when one looks down onto the object from the top. The projection of an object onto imaginary planes to obtain multiple views (e.g., views from the front or side of the object) was not utilized until the Italian architects, Alberti and Brunelleschi, theorized the concept in the 15th Century (Giesecke et al., 1975). According to Giesecke et al., Leonardo da Vinci’s treatise on painting, published in 1651, is regarded as the first book ever printed on the theory of projection drawing. Da Vinci’s drawings were more artistic than engineering like and served as schematics for one of a kind machines, since designs from this era did not utilize interchangeable parts (Jensen et al., 2008).

As design concepts and intent became more complicated, Giesecke et al., (1975) noted that the need for a more descriptive drawing methodology emerged. Gaspard Monge, a French mathematician considered to have invented descriptive geometry near the close of the 18th Century, developed the principles of projection that, currently, are the basis of technical drawing. Descriptive geometry is the projection of three dimensional figures on the two dimensional plane of paper in a manner that allows geometric manipulations to determine lengths, angles, shapes, and other geometric information about figures (Earle, 2008). Graphic solutions of three dimensional forms requires an understanding of spatial relationships. Problems that required mathematical solutions could now be solved graphically, through the use of descriptive geometry, with an accuracy that provided for manufacturing and construction (Jensen et al., 2008). Technical drawings developed, which used descriptive geometry, and became the methodology for design representation for the next 200 years and provided a scientific foundation to engineering design graphics (Barr & Juricic, 1994).

The integration of design graphics into the engineering education curriculum in the U.S. can be traced to the Military Academy at West Point in 1807. The introduction of design graphics into the West Point engineering program provided for a strong foundation to the subject of drawing (Barr & Juricic, 1994). The Morrill Act of 1862 (as cited in Barr & Juricic) assisted with the emergence of more technical schools, and hence, the progression of engineering schools and engineering design graphics in the curricula. The Act gave to every state, which had remained in the Union, a grant of 30,000 acres of public land for every member of its congressional delegation. Since, under the Constitution, every State had at least two senators and one representative, even the

smallest state received 90,000 acres. The States were to sell this land and use the proceeds to establish colleges in engineering, agriculture, and military science. Over 70 land grant colleges, as they came to be known, were established under the original Morrill Act (U.S. Department of State, 2009). By the turn of the century, drawing standards developed, and the discipline matured (Barr & Juricic).

Simultaneous with the progression of the discipline of engineering graphics, technical drawing equipment evolved over time (Giesecke et al., 1975). The scrawling compass utilized by the Romans remained in use during Leonardo da Vinci's time, and circles were still scratched with metal points. By the 17th Century, reed pens had been replaced by quills made from bird feathers (Giesecke et al.).

The scribbling compass gave way to the graphite compass shortly after the development of graphite pencils in the 18th Century (WorldLingo, 2009). Protractors, used to measure and draw segments of a circle, were in use during the 13th Century. Early technical pens of the 1600s could control line width through the use of two curved metal stylus pieces joined by an adjustable screw. These ruling pens controlled the flow of ink onto the paper. This basic pen model was maintained, with minor modifications, until the 1960s, when German technical drawing pens appeared on the market. In the 1960s, drawing pens were developed to draw a line with a specific width (WorldLingo).

Drafting tables evolved from the utilization of a sliding horizontal straightedge, or T-square, to a parallel bar guided by wires affixed on each side of the table (Monahan, 2005). Challenges with drafting accuracy existed with these systems until the introduction of the *drafting machine* in the 1970s. This invention provided for increased

manual drafting speed and accuracy and was considered the industry standard until the arrival of computer aided drafting.

Equipment changed radically during the 1990s, when computer-aided drafting almost completely ousted drawing by hand (WorldLingo, 2009). Technical design changed from drawing by hand to the production of CAD drawings, where drawings were no longer drawn, but were built from a virtually produced model (WorldLingo, 2009). Like most great inventions, CAD drafting had humble beginnings, but the potential was immediately recognized by software companies, engineers, and programmers. The first CAD programs in the 1970s were very expensive, and only large companies could afford the computers to run the programs. Initially, they could only create two dimensional (2D) drawings similar to the hand drafted drawings of the era. However, these early simple programs changed the face of manufacturing and construction design, and they quickly evolved over the years as computer processing speed, power, and graphics capabilities increased. During the 1980s, the next major step toward modern CAD was achieved with the advent of three dimensional (3D) solid modeling. As computing prices came down, the power of CAD became available to smaller companies. Computer aided drafting is now used in all phases of design across all engineering industries (Cadbuilt, 2007).

Just as the old days of fine line drawings and of shading and washes are gone forever; no artistic talent is necessary for the modern technical student to learn the fundamentals of the graphic language (Giesecke et al.,1975). All authorities agree that the ability to think in three dimensions is one of the most important requisites of the successful engineer. This training to visualize objects in space, to use the constructive

imagination, is one of the principal values to be obtained from a study of the graphic language. The ability to visualize is possessed in an outstanding degree by persons of extraordinary creative ability (Giesecke et al.).

Visual and Spatial Relationships

Illustrations are a powerful aid to understanding nonquantitative information (Kirsh, 2001). In geometry, illustrations can help students to understand problems and reason in a constructive manner toward a solution. In physics, they help students to grasp principles that may be difficult to comprehend. Often, the display of parts and assemblies relies on techniques, such as explosions and canonical views, to communicate the global structure and relation of a system that may have hidden pieces (Kirsh).

Engineers use visualization and spacial reasoning in tasks like the design and documenting of parts to be assembled, to imagine the shape of cut hillsides for highway construction, to lay out circuit designs, or to find optimal crystal configurations (Hsi, Linn, & Bell, 1997). Engineering graphics requires advanced visualization skills. Visualization is essential in design, drawing, and interpretation (Hsi et al.). In the creative design process, images are constructed in the mind as pictorial images, then translated to engineering sketches for conceptual design and later to multiview drawings (see Figure 3) for engineering and manufacturing applications. The ability to visualize typical engineering tasks, such as the relationship between a three dimensional (3D) object and its companion two dimensional (2D) multiview, can be problematic for students (Crown, 2001). Also, the ability to mentally rotate the object is a key component (Hsi et al.).

Figure 3. Glass box principle.³

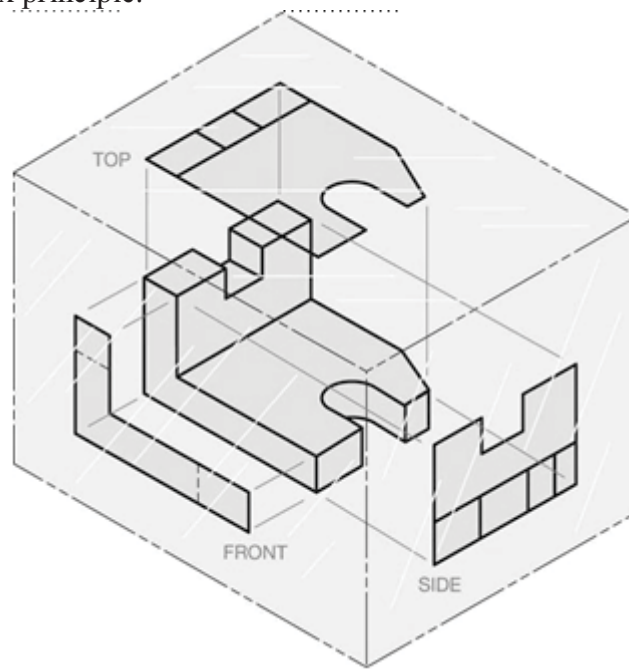


Figure 3. Projection of a 3D object onto multiple 2D planes.

³From “*Engineering Drawing & Design*,” by C. Jensen, J.D. Helsel and D.R. Short, 2008, p. 11.

Engineering Sketches

Sketching is one of many drafting techniques (Walker & Mathis, 2007).

Sketching is a quick way to show an idea that would be difficult to describe with words alone. Industry uses many sketching techniques to develop engineering concepts (Walker & Mathis, 2007). Even during the era when mechanical drawing with instruments prevailed, many engineers considered the ability to render serviceable sketches to be of even greater value to them than skill in instrument drawing (Giesecke et al., 1975).

However, CAD does not replace the need for sketching in the design process.

Engineering graphics relies upon the interactive sketching process (Jensen et al., 2008). Practice in sketching helps the student to develop a good sense of proportion and accuracy of observation (Jensen et al.). Lipson and Shpitalni (2000) observed that sketching appears to be important for the following reasons: (a) it is fast, suitable for the

capacity of short term memory; (b) it is implicit, that is, it describes form without a particular sequential structure; (c) it serves for analysis, completeness check, and simulation; (d) it is inexact and abstract, avoids the need to provide unnecessary details, and (e) it requires minimal commitment and is easy to discard and start anew.

Often, the term, sketching, is associated with crude or careless freehand drawing in which no effort has been levied (Walker & Mathis, 2007). Sketching is accomplished in a freehand manner, most often with the use of a pencil, paper, and eraser. However, sketching requires care with attention to basic geometric principles (Walker & Mathis). For example, line types such as center, hidden, extension, dimension, section, and phantom carry special meanings and should be used accordingly. Geometric shapes, such as squares, rectangles, circles, arcs, ellipses, and polygons, should be sketched following standardized methodologies. Also, proportion, or the comparative relation between objects, is important in sketching, especially in the proportion of the ratio of height to width (Giesecke et al., 1975). Not all sketching needs to be done entirely freehand on blank paper if there are faster methods that can be used. Sketching paper, or grid paper, for orthographic or pictorial views enhances a student's capability. Long lines can sometimes be drawn faster with the use of a straightedge. Also, circles, ellipses, and polygons can be drawn with the use of a template (Jensen et al., 2008).

Pictorial sketching is used to help the designer work out problems in space, including clearances and interferences, and to aid in the power of visualization (Jensen et al., 2008). Pictorial drawings include axonometric projections of which isometrics are classified. Isometric views are natural to the viewer's eye and are one of the most widely used pictorial methods (Walker & Mathis, 2007). Isometric drawings are based on a

procedure in which the object is revolved at an angle of 45 degrees to the horizontal, so that the front corner of the object is toward the viewer, and then the object is tipped up or down at a 35 degree and 16 minute angle. When this rotation is done to a cube (see Figure 4), the three visible faces appear equal in shape and size, and the side faces are at an angle of 30 degrees to the horizontal (Jensen et al.).

*Figure 4. Isometric drawing.*⁴

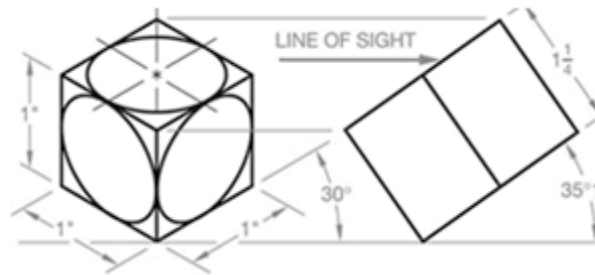


Figure 4. Isometric drawing based on true measurement in isometric view.

⁴From “*Engineering Drawing & Design*,” by Jensen et al., 2008, p. 11.

Scaling

In the discipline of engineering, once the design transitions from the conceptual sketching phase to the production phase, the ability to scale drawings in both the virtual CAD environment and paper document environment becomes critical (Barr & Juricic, 1994). The term, scale, has dual meanings in drafting. A scale is a measuring device (see Figure 5). However, also, the term scale refers to the size to which an object is drawn and plotted (Walker & Mathis, 2007). As a measuring instrument, a scale can be used to make measurements that are full size, larger than full size, or smaller than full size. In the CAD domain, designs are drawn at full scale and the plotting scale is manipulated for publishing purposes. The ability to draw the design once and publish at multiple scales automatically is one of the most powerful features of CAD.

Figure 5. Full Scale.⁵

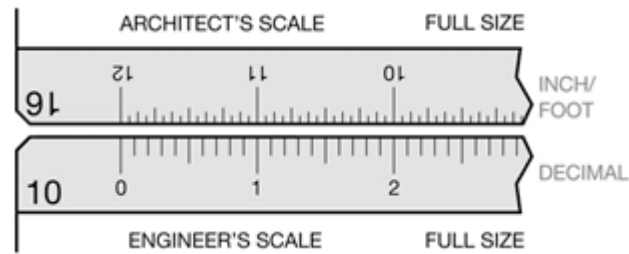


Figure 5. Comparison of a full engineer's scale (10) and architect's scale (16).

⁵From "Engineering Drawing & Design," by Jensen et al., 2008, p. 11.

Measurements on published drawings are based on either the US Customary (inch) or the SI Metric (meter) systems (Walker & Mathis, 2007). In the US Customary system, measurements are produced by the: (a) architect's scale, or (b) engineer's scale. In the SI system, the metric scale is utilized. The architect's scale is most frequently used in the production of drawings for buildings. Typically, these drawings represent a large reduction in size in order to fit on standard size plotting media. For this reason, architect's scales are designed to make measurements in feet. For example, a drawing published at $1/4" = 1'-0"$ scale means that 1/4 inch on the drawing represents 1 foot on the actual object (see Figure 6; Walker & Mathis).

Figure 6. Architect's scale.⁶

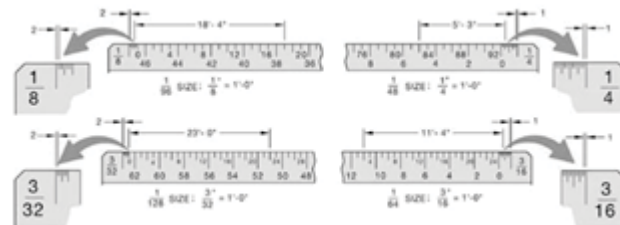


Figure 6. Architect's scale example.

⁶From "Engineering Drawing & Design," by Jensen et al., 2008, p. 11.

The engineer's scale is extremely versatile and is frequently used where large reductions are required, such as in large civil engineering projects (Walker & Mathis, 2007). An engineer's scale can be used to scale a reduction or an enlargement. For example, reductions may be 1 inch equals 100 feet ($1''=100'$), or 1 inch equals 1000 feet ($1''=1000'$). Enlargements may be 1 inch equals 0.1 feet ($1''=0.1'$), or 1 inch equals 0.01 feet ($1''=0.01'$; see Figure 7).

Figure 7. Engineer's scale.⁷

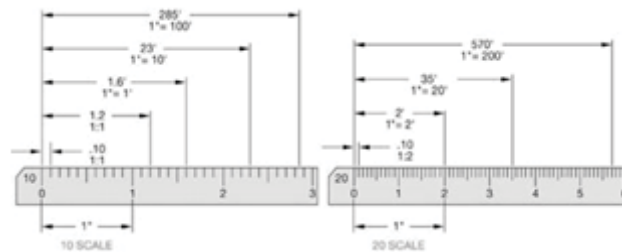


Figure 7. Engineer's scale example.

⁷From "Engineering Drawing & Design," by Jensen et al., 2008, p. 11.

Chapter Summary

As shown in the review of literature, ENT 131 is not regularly integrated into a variety of programs in the CCCS (2008). Furthermore, in the majority of programs that incorporate engineering graphics into their curricula, CAD is perceived as the prerequisite or foundational course in the program, not ENT 131. This author believes that this is an indicator that ENT 131 is no longer relevant in CET.

The field of engineering design graphics has progressed from the use of drafting tables and T-squares to computer aided drafting (CAD). Although these advancements are impressive, fundamental concepts remain important. This author believes that

sketching is vital to visualization and spatial skills and that the ability to scale drawings in both the virtual CAD environment and paper document environment is critical.

In keeping with this progression, in Chapter 3, Method, the author details the procedures for the project. Methods examined include the target audience, organization of the project, and the peer assessment plan.

Chapter 3

METHOD

The purpose of the project was to design a course that would take the important and relevant skill building concepts of scaling, sketching, geometric construction and spatial imagination from ENT 131 and integrate them into an existing computer aided drafting (CAD) course; thereby, a hybrid mechanical drawing-computer aided drafting course was developed. The objective was to provide the student with a course that is relevant in academia and industry. Currently, at Pueblo Community College (PCC), a majority of the civil engineering technology (CET) students enrolled in ENT 131 believed that the class has negligible value in the curricula. As a faculty member at PCC, this author believed that ENT 131 is the incorrect prerequisite for courses in the CET Program. Accordingly, the methodology utilized to develop the hybrid course is presented below.

Target Audience

The hybrid course was designed for first year college students enrolled in the CET program at PCC, but the concepts are also applicable to non-first year students, Advanced Vocational Education Program (AVEP) students, and Post Secondary Education Options Act (PSEOA) students interested in CET. The Department Chair and Dean of the Engineering Technology program, together with the members of the Curriculum Committee and Vice President of Learning of PCC, found the project information valuable.

Students who enrolled in the hybrid course emulated the demographics of the college. The average student age was 29 years, and about one-third were first time college students. Approximately 80% received financial assistance in the form of grants, scholarships, work-study jobs, and/or student loans and many work full time jobs and have family obligations. Approximately 39% represented a minority. Pueblo Community College has been designated by the U.S. Department of Education as a Hispanic-Serving Institution based on the commitment of the college to serve Hispanic and low income students (PCC; 2009).

Organization of Project

Instructional design procedures utilized in the creation of the hybrid course included a training needs assessment, a topical outline analysis, and the development of lesson plans supported by on-line lecture and video training modules. The project is designed as a hybrid curriculum to be delivered over a 16 week period by means of 110 minute duration classes that meet twice per week. In Chapter 4, this author includes the results of a needs assessment, a topical outline for the hybrid course, and hybrid lesson plans that incorporate the relevant skill building concepts of scaling, sketching, geometric construction and spatial relationships into the CAD curriculum. The hybrid lesson plans address: (a) learner outcomes, (b) instructional strategies, (c) materials requirements, (d) pre-assessment, (e) lesson content, (f) anticipatory problem sets, (g) guided practice, (h) self-directed learning, (i) post assessment, and (j) instructor reflection. The training modules that support each topic are 3 to 5 minute videos that demonstrate the technical subject. The training modules are available to students at any time on the institutions' learning management system. The video modules extend the classroom and provide

systematic instruction and self-directed learning opportunities to the students beyond the normal meeting times.

Experiential learning is provided through hands-on opportunities to sketch and draw industry relevant objects and not just academic widgets. For example, problems from the author's engineering consulting background are integrated into the lesson plan problem sets. Also, working students are encouraged to present relevant work problems to the class.

Lifelong learning (LLL) and self-directed learning (SDL) concepts are introduced early in the lesson plan as a method to promote and encourage students to attain those attributes. It is important for engineers to keep their knowledge and skills relevant for global competitiveness, employability, and occupational requirements. Engineering students must learn that professional skills are dynamic and require continuous upkeep and upgrading.

Assessment of the hybrid curriculum was accomplished in two formats: (a) weekly evaluation of student understanding within a topic and (b) student surveys at mid and final points in the lesson plan. The weekly evaluation of student topical understanding is attained by appraisal of the student's mastery of the assigned problem set. Surveys ask the student to rate the following course components over a range of effectiveness measures: (a) LLL/SDL, (b) scaling, (c) sketching, (d) AutoCAD basics, (e) on-line lecture presentations, and (f) video tutorials.

Reflection is incorporated into the lesson plans as a means to promote student focused teaching and provide instructors with the opportunity to reflect on their efforts.

Instructors are encouraged to experiment with course materials, lecture methods, and andragogical techniques based on their evaluation of assessment data.

Peer Assessment Plan

The hybrid curriculum was presented to colleagues in academia and industry for review and comment. The review panel included two college professors, one industry professional, and one CET student. This author facilitated a panel discussion as a means to query the group for feedback on the hybrid curriculum's relevancy and ease of implementation. Their assessment is discussed in Chapter 5.

Chapter Summary

This author utilized the relevant skill building concepts of scaling, sketching, geometric construction, and spatial relationships in the development of a hybrid mechanical drawing-computer aided drafting course. The primary target group is first year engineering technology students who require a foundation in computer aided drafting for subsequent coursework and relevant skills in industry. In Chapter 4, Results, this author presents the outcome of a needs assessment, topical outline analysis, and hybrid lesson plans with a discussion of the completed project in Chapter 5.

Chapter 4

RESULTS

Introduction

The instructional material covered in ENT 131-Mechanical Drawing 1 (ENT 131), for the most part, is no longer relevant to the engineering graphics skills required in industry and, therefore, should no longer be a course in the Civil Engineering Technology (CET) curriculum at Pueblo Community College (PCC).

The purpose of this project was to design a course that would take the important skill building concepts of scaling, sketching, geometric construction, and spatial imagination from ENT 131 and integrate them into a computer aided drafting (CAD) course; thereby developing a hybrid course. The objective was to provide the student with a course that is relevant in academia and industry without increasing the number of required credits in the CET curricula.

Hybrid Course Design

Instructional design procedures utilized in the creation of the hybrid mechanical drawing-computer aided drafting course include: (a) training needs assessment, (b) topical outline analysis, and (c) hybrid lesson plans supported by on-line lecture materials and video training modules.

Needs Assessment

The needs assessment for the project focused on determining what engineering graphic skills were needed for CET student success in academia and industry.

Assessments were conducted through informal, free-form interviews of industry professionals and students along with observation of student performance in more progressive courses taught by the project's author.

The needs assessment indicated that civil engineering professionals in the private and government sectors use CAD to produce technical drawings. However, sketching is used to communicate a concept or design intent initially before moving to CAD production. The majority of CET students enrolled in ENT 131 believed that the class has negligible value in the curriculum because too much time and effort is applied to extraneous activities such as lettering, line quality, erasing and redrawing. Additionally, students in the civil engineering discipline indicated that ENT 131 only offered instruction in the area of mechanical or manufacturing engineering drawings. Observations by the author in more progressive drawing courses in the CET curriculum revealed that students who have successfully completed ENT 131 possess inadequate retention of scaling, geometric construction and spatial imagination skills. This may be a result of: (a) lack of instructional emphasis in the civil engineering discipline, or (b) students' perception that the task is extraneous and retention efforts are trivialized.

Topical Outline and Lesson Plan Analysis

The topical outline and lesson plans for the hybrid course integrates scaling, sketching, geometric construction and special relationship skills into the CAD curriculum. Also, lifelong learning (LLL) and self-directed learning (SDL) concepts are introduced at the beginning of the 16 week period as an andragogical strategy. The SDL concept is fundamental to success in the CET program, and the concept is reinforced throughout the period with independent learning and practice opportunities.

Hybrid Curriculum 16 Week Topical Outline

Week 1

Course introduction and standard rules of engagement
Lifelong learning and self-directed learning concepts and attributes

Week 2

Introduction to scaling

Week 3

Introduction to technical sketching
Introduction to basic line types

Week 4

Introduction to CAD
Introduction to coordinate systems
Introduction to line, ortho and erase commands

Week 5 and 6

Model and paper space
Attributed title blocks
Layer management, pen weights and plotting basics

Week 7

Basic drawing tools for circles, arcs, ellipses, polygons, and rectangles

Week 8

Object modification

Week 9

Dimensioning

Week 10

Text styles and multiline text

Week 11 and 12

Sketching orthogonal projections
Multiview sketching

Week 13 and 14

Isometric drawing

Week 15 and 16

Introduction to 3D solids

Hybrid Lesson Plan

Week 1

Topics:

Course introduction and standard rules of engagement
Lifelong learning and self-directed learning concepts and attributes

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret the course syllabus and outline.
Students will be able to log onto computer network.
Students will be able to access the on-line learning management system.
Students will be able to comprehend the concept of lifelong and self-directed learning.
Students will be able to list the attributes of a self-directed learner.

Instructional Strategies:

Primarily a lecture with the delivery of important course information and concepts
Secondarily a lab with experiential learning opportunities

Materials Needed:

Smart Board
Access to the on-line learning management system
Copies of course syllabus
Lecturer PowerPoint presentation available on course syllabus and outline
Lecturer PowerPoint presentation available on LLL/SDL
Training module available on network and learning management system logon

Pre-Assessment:

Do students have the proper credentials to log onto the network and access the on-line learning management system? If not, direct students to computer help department and emphasize the importance of access to the network, class information and software.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor will highlight pertinent course information.

Using the Smart Board and the computer, demonstrate access to the on-line learning management and course management system. Demonstrate access to the on-line course syllabus, course outline and training modules.

Using the Smart Board and a PowerPoint presentation, the instructor will present lifelong and self-directed learning concepts and attributes.

Anticipatory Problem Set:

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students are directed to access the various components of the learning management system from their workstations and the instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students access the course syllabus, outline and training modules?

Did students participate in lifelong and self-directed learning discussion?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 2

Topics:

Introduction to scaling

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use an architect's scale.

Students will be able to interpret and use an engineer's scale.

Students will be able to indicate the importance of scaling.

Instructional Strategies:

Primarily a lecture with the delivery of important course information and concepts

Secondarily a lab with experiential learning opportunities using the two scales

Materials Needed:

Smart Board

Access to the on-line learning management system

Architect's scale

Engineer's scale

Lecturer PowerPoint presentation available on scaling

Training module available on scaling techniques

Scaling worksheets

Pre-Assessment:

Do students have an architect and engineer's scale? If not, direct students to purchase the equipment and emphasize the importance of scaling.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basic components of each scale, and how it will be used in the classroom and industry.

Using the Smart Board and the computer, demonstrate how to use each scale.

Demonstrate access to the on-line scale training modules.

Anticipatory Problem Set:

Scaling worksheets will provide practice on scaling lines and shapes to obtain length, area and volume data. The architect and engineer's scales are utilized.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students are provided scaling worksheets to complete in class under the direction of the instructor. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish worksheets outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret and use an architect's scale?

Did students interpret and use an engineer's scale?

Can students communicate the importance of scaling?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 3

Topics:

Introduction to sketching
Introduction to basic line types

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to indicate the importance of sketching.
Students will be able to sketch basic geometric shapes and line types.

Instructional Strategies:

Primarily a lab with experiential learning opportunities to sketch
Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board
Access to the on-line learning management system
Mechanical pencil
Eraser
Grid paper
Lecturer PowerPoint presentation available on sketching
Training module available on sketching
Sketching worksheets

Pre-Assessment:

Do students have mechanical pencil, eraser and grid paper? If not, direct students to purchase the equipment and emphasize the importance of sketching.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basic components of sketching, and how it will be used in the classroom and industry.

Using the Smart Board and the computer, demonstrate how to sketch. Demonstrate access to the on-line sketching training modules.

Anticipatory Problem Set:

Sketching worksheets will provide practice on sketching techniques for basic geometric construction.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students are provided sketching worksheets to complete in class under the direction of the instructor. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish worksheets outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret and apply fundamental sketching procedures to geometric shapes?
Can students communicate the importance of scaling?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 4

Topics:

Introduction to AutoCAD
Introduction to coordinate system
Introduction to line, ortho and erase commands

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to launch the AutoCAD program.
Students will be able to interpret the AutoCAD drawing environment.
Students will be able to access the tool tips and help.
Students will be able to interpret and use line, ortho and erase commands.
Students will be able to interpret and use the rectangular, relative and polar coordinate systems.

Instructional Strategies:

Primarily a lecture with the delivery of important information and concepts
Secondarily a lab with experiential learning opportunities using the AutoCAD software

Materials Needed:

Smart Board
Access to the on-line learning management system
Lecturer PowerPoint presentation available on the AutoCAD drawing environment
Lecturer PowerPoint presentation available on the coordinate systems
Training module available on coordinate systems, lines and erasing
External USB storage device
Required course textbook
Coordinate system worksheets

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basic components of the AutoCAD environment and how it will be used in the classroom and industry.

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the coordinate systems used in AutoCAD and how they are used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to access the AutoCAD software. Demonstrate various components in the AutoCAD environment. Demonstrate use of the three coordinate systems.

Anticipatory Problem Set:

Basic geometric shapes will provide practice on each of the coordinate systems as well as provide practice on using the line, ortho and erase AutoCAD commands.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students access the AutoCAD software and draw basic objects using the line command and the three coordinate systems. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish worksheets outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students launch the AutoCAD program?

Did students interpret the AutoCAD drawing environment?

Did students access the tool tips and help?

Did students interpret and use the line, ortho and erase commands?

Did students interpret and use the coordinate systems to complete the worksheets?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 5

Topics:

Model and paper space
Attributed title blocks

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use model space.
Students will be able to interpret and use paper space.
Students will be able to interpret and use attribute definitions.
Students will be able to construct a title block.

Instructional Strategies:

Primarily a lab with experiential learning opportunities using the AutoCAD software
Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board
Access to the on-line learning management system
Lecturer PowerPoint presentation available on model and paper space environments
Lecturer PowerPoint presentation available on attributed title block construction
Training module available on model and paper space, and attributed title blocks
External USB storage device
Required course textbook
Title block worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on model space and paper space environments and how they will be used in the classroom and industry.

Using the Smart Board and a PowerPoint presentation, the instructor lectures on attribute definitions, how they differ from text, and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use model space, paper space, attribute definitions, and a title block.

Anticipatory Problem Set:

Students will follow worksheet guidelines to construct a personalized attributed title block.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned title block in lab. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the title block outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret and use model space?

Did students interpret and use paper space?

Did students interpret and use attribute definitions?

Did students construct a title block?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 6

Topics:

Layer management
Pen weights
Plotting basics

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret, create, and manage drawing layers.
Students will be able to interpret and use basic line types.
Students will be able to draw objects on specific layers.
Students will be able to interpret and use pen weights via plot style tables.
Students will be able to plot in paper space to scale.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object then in using the AutoCAD software to construct the object

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board
Access to the on-line learning management system
Lecturer PowerPoint presentation available on layer management
Lecturer PowerPoint presentation available on pen weights
Lecturer PowerPoint Presentation available on plotting basics
Training modules available on layer management, pen weights, and plotting basics
External USB storage device
Required course textbook
Pencil
Eraser
Scales
Grid paper
Drawing worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basics of layer management and how they will be used in the classroom and industry.

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basics of pen weights via plot style tables and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use layer management, pen weights, and plotting to scale.

Anticipatory Problem Set:

Basic geometric shapes will provide practice on layer management, pen weights, and plotting drawings to scale.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching on grid paper then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret, create, and manage drawing layers?

Did students interpret and use basic line types?

Did students draw objects on specific layers?

Did students interpret and use pen weights via plot style tables?

Did students plot in paper space to scale?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 7

Topics:

Basic drawing tools for: circle, arc, ellipse, polygon, and rectangle

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use the circle command.

Students will be able to interpret and use the arc command.

Students will be able to interpret and use the ellipse command.

Students will be able to interpret and use the polygon command.

Students will be able to interpret and use the rectangle command.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object, then in using the AutoCAD software to construct the object.

Secondarily a lecture with the delivery of important information and concepts.

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on the various basic drawing tool commands

Training modules available on drawing circles, arcs, ellipses, polygons, and rectangles

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Basic drawing tools worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basic drawing tools for circles, arcs, ellipses, polygons, and rectangles in AutoCAD and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use the basic drawing tools for circles, arcs, ellipses, polygons, and rectangles.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching and on using the circle, arc, ellipse, polygon, and rectangle AutoCAD commands.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching on grid paper then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students use the circle command?

Did students use the arc command?

Did students use the ellipse command?

Did students use the polygon command?

Did students use the rectangle command?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 8

Topics:

Object modification

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use the fillet and chamfer command.

Students will be able to interpret and use the trim and extend command.

Students will be able to interpret and use the stretch and lengthen command.

Students will be able to interpret and use the break command.

Students will be able to interpret and use the scale command.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object, then in using the AutoCAD software to construct the object

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on object modification

Training module available on object modification

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Object modification worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basics object modification methods and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use a variety of object modification commands.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching and on using the fillet, chamfer, trim, extend, stretch, lengthen, and scale AutoCAD commands.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching the object on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students use the fillet and chamfer command?

Did students use the trim and extend command?

Did students use the stretch and lengthen command?

Did students use the break command?

Did students use the scale command?

Mid semester survey to gauge student perception of the course

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 9

Topics:

Dimensioning

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use annotative dimensioning.

Students will be able to interpret and use linear and aligned dimensions.

Students will be able to interpret and use angular dimensions.

Students will be able to interpret and use radial dimensions.

Students will be able to interpret and use multileaders.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object, then in using the AutoCAD software to construct the object

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on dimensioning

Training module available on dimensioning

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Dimensioning worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on annotative dimensioning and how it will be used in the classroom and industry.

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the various dimension styles and how they will be used in the classroom and industry.

Using the Smart Board and a PowerPoint presentation, the instructor lectures on multileaders and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use annotative dimensioning and multileader styles.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching and on dimensioning various objects.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching the object on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret and use annotative dimensioning?
Did students interpret and use linear and aligned dimensions?
Did students interpret and use angular dimensions?
Did students interpret and use radial dimensions?
Did students interpret and use multileaders?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 10

Topics:

Text styles and multiline text

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use annotative text.

Students will be able to interpret and use single line text.

Students will be able to interpret and use multiline text.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object, then in using the AutoCAD software to construct the object and label

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on text styles, single line, and multiline text

Training module available on using text

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Text worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on annotative text and how it will be used in the classroom and industry.

Using the Smart Board and a PowerPoint presentation, the instructor lectures on single line and multiline text and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use annotative text.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching and on labeling using annotative, single line, and multiline text.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching the object on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students use annotative text?

Did students use single line text?

Did students use multiline text?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 11

Topics:

Sketching orthogonal projections

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret orthogonal projection.

Instructional Strategies:

Primarily a lecture with the delivery of important information and concepts

Secondarily a lab with experiential learning opportunities in sketching

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on orthogonal projection

Training module available on orthogonal projection

Required course textbook

Pencil

Eraser

Scales

Grid paper

Orthogonal worksheet

Pre-Assessment:

Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on orthogonal projection and how it will be used in the classroom and industry.

Using the Smart Board and computer, demonstrate orthogonal projection.

Anticipatory Problem Set:

Basic geometric shapes will provide practice on sketching missing lines of objects from specific viewpoints.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab by sketching on grid paper. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret orthogonal projection?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 12

Topics:

Multiview sketching

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use multiview sketches.

Instructional Strategies:

Primarily a lecture with the delivery of important information and concepts

Secondarily a lab with experiential learning opportunities in sketching

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on multiview sketching

Training module available on multiview sketching

Required course textbook

Pencil

Eraser

Scales

Grid paper

Multiview sketching worksheet

Pre-Assessment:

Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the multiview concept and shows how it will be used in the classroom and industry.

Using the Smart Board and computer, demonstrate multiview sketching.

Anticipatory Problem Set:

Basic geometric shapes will provide practice on sketching top, front, and right side views.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab by sketching the object on grid paper. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students interpret multiview sketching?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 13

Topics:

Isometric drawing

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use the isometric snap.

Students will be able to interpret and use the isometric ellipse.

Students will be able to interpret and use mutiview projections.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object, then in using the AutoCAD software to construct the isometric and multiview objects.

Secondarily a lecture with the delivery of important information and concepts.

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on isometric drawings

Training modules available on drawing isometric and multiview drawings

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Basic drawing tools worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the isometric snap and isometric ellipse in AutoCAD and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use the isometric snap and isometric ellipse.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching the object and on drawing isometric and multiview drawings in AutoCAD.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students use the isometric snap?

Did students use the isometric ellipse?

Did students use mutiview projections?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 14

Topics:

Isometric drawing continued

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use the isometric snap.

Students will be able to interpret and use the isometric ellipse.

Students will be able to interpret and use multiview projections.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object then in using the AutoCAD software to construct the isometric and multiview objects

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on isometric drawings

Training modules available on drawing isometric and multiview drawings

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Basic drawing tools worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the isometric snap and isometric ellipse in AutoCAD and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to use the isometric snap and isometric ellipse.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching and on drawing isometric and multiview drawings in AutoCAD.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students use the isometric snap?

Did students use the isometric ellipse?

Did students use mutiview projections?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 15

Topics:

Introduction to 3D solids

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and use 3D solid primitives.

Students will be able to interpret and use the union command.

Students will be able to interpret and use the subtract command.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object then in using the AutoCAD software to construct the 3D objects

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on 3D primitive objects

Lecturer PowerPoint presentation available on union and subtract commands

Training modules available on drawing various 3D primitive objects

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Basic drawing tools worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basic 3D primitive drawing tools in AutoCAD and how they will be used in the classroom and industry.

Using the Smart Board, computer, and AutoCAD software, demonstrate how to use 3D primitive objects.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching and on drawing basic 3D objects using primitive building blocks as well as combining and subtracting blocks.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching the object on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students use 3D solid primitives?

Did students use the union command?

Did students use the subtract command?

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Hybrid Lesson Plan Week 16

Topics:

Introduction to 3D solids (continued)

Duration and Class Format:

Two 110 minutes classes consisting of lecture and lab

Learner Outcomes:

Students will be able to interpret and extrude 2D profiles.

Students will be able to interpret and extrude planar surfaces.

Instructional Strategies:

Primarily a lab with experiential learning opportunities first in sketching the object, then in using the AutoCAD software to construct the 3D objects

Secondarily a lecture with the delivery of important information and concepts

Materials Needed:

Smart Board

Access to the on-line learning management system

Lecturer PowerPoint presentation available on extrusion

Training modules available on drawing various extrusions

External USB storage device

Required course textbook

Pencil

Eraser

Scales

Grid paper

Basic drawing tools worksheet

Pre-Assessment:

Do students have the required course textbook and the highly recommended external storage device? Do students have the required pencil, eraser, scales, and grid paper? If not, direct students to purchase the equipment and emphasize the importance.

Lesson Content:

Using the Smart Board and a PowerPoint presentation, the instructor lectures on the basics of 2D and planar surface extrusion in AutoCAD and how they will be used in the classroom and industry.

Using the Smart Board, computer and AutoCAD software, demonstrate how to extrude profiles and surfaces.

Anticipatory Problem Set:

Basic geometric shapes will provide continued practice on sketching, and 2D profiles and surfaces will be extruded to 3D objects.

Presentation slides and the training module are available on the course web site for downloading.

Guided Practice:

Students complete the assigned problems in lab first by sketching the object on grid paper, then by drawing in AutoCAD. The instructor will check individual mastery and assist as needed.

Self-Directed Learning:

Students are encouraged to finish the assigned problems outside of class as needed.

Students are encouraged to read chapters prior to class and access the on-line training modules. Additionally, students are encouraged to become part of the Autodesk student community, download AutoCad software onto their personal computer, and learn independently outside the classroom.

Post Assessment:

Did students extrude 2D profiles?

Did students extrude planar surfaces?

End of semester survey to gauge student perception of the course

Reflection:

Instructor should reflect on the lesson plan and is encouraged to experiment with course materials, lecture methods, and andragogical techniques based on critical evaluation of assessment data.

Chapter Summary

The hybrid course design presented in this Chapter provides for the logical integration of scaling, geometric construction, sketching, and spatial imagination into the existing computer aided drafting course. The topical outline provides the overall basis for the 16 week course, while the lesson plans guide the weekly instructional content. To assist in making the instructional content available to the students at all times, lecturer presentation slides and video training modules are available on the course web site for downloading. In Chapter 5, Discussion, the project's overall contribution is evaluated.

Chapter 5

DISCUSSION

Student perception of the value of a course within a program must be evaluated carefully, and its result should be coupled with other assessment tools when making a final assessment. However, student perception is a powerful barometer of opinion, and its energy can affect student recruitment and retention as well as industry partnerships. The author's exposure to such perceptions, coupled with classroom observations, informal survey results and over 25 years of relevant professional experience, provided for the problem statement validation. The literature review demonstrated that ENT 131 is not regularly integrated into CET programs in the CCCS and that CAD courses are the foundational courses.

A review of the topics covered in mechanical drawing and their applicability to other courses in the CET program and industry provided for the recognition of salient program topics. In the author's opinion, skills such as learning how to use the engineer's and architect's scale, geometric construction, sketching, and spatial imagination skills are salient and were integrated into the basic CAD curriculum. The author believes that the use of paper sketching, as an introduction to geometric and spatial skills, is appropriate in a CAD course if the learning connection is made between the paper sketch and the computer skill.

Contribution of the Project

This project resulted in a hybrid curriculum specifically designed to integrate the relevant mechanical drawing skills of scaling, geometric construction, sketching, and spatial imagination into the basic CAD course. The hybrid curriculum provides for a relevant skill set for the CET curricula and for industry without increasing the number of credits in the program. The integration of lifelong and self-directed learning concepts into the curriculum provides the student with opportunities to develop these important attributes.

Limitations

Two limitations were notable. First, a significant amount of time was required to build the video training modules. This time constraint may be burdensome if the subject matter expert also teaches the course. Secondly, a peer evaluation team with a variety of expertise may be needed for assessing mid-term and end-of-term survey results.

Peer Assessment Results

The hybrid curriculum was reviewed by colleagues in academia and industry for relevancy, ease of implementation, and general applicability to the CET program. Two experienced college instructors, one at the university level and one at the community college level, comprised the academic review, along with one industry professional in the workforce training field and one community college CET student.

All of the reviewers agreed that the hybrid curriculum was relevant to both academia and industry. Furthermore, the reviewers acknowledged that design ideas and intent are first accomplished through sketching before progressing into CAD. The reviewers believed that, with the integration of scaling, sketching, geometric

construction, and spatial reasoning into the CAD curriculum, the basic CAD course has emerged as an excellent introduction to engineering graphics.

The on-line accessibility of instructional material and video training modules was highly regarded. The reviewers believed that, if students would use the materials prior to class, lecture and lab periods would be utilized more efficiently. Concern was expressed that potentially, with the ease of access to lecture and training material, class attendance may decline.

Recommendations for Further Development

Pre-visualization testing at the start of the course may be beneficial for fine tuning instructional strategies. The introduction to 3D modeling at the end of the curriculum may develop further to include a rapid hardcopy prototype of the design.

Project Summary

The hybrid mechanical drawing-computer aided drafting course provides the civil engineering technology student with relevant academic and industry skills in a single course. Implementation of the hybrid course eliminates ENT 131 from the civil engineering technology program, thereby making this hybrid course the foundational pre-requisite in the program.

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