Review of a Possible Model for Technology Aided Engineering Design Graphics

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Abstract

This research project looks at the present state of 2-D Visualization. It uncovers 3-D Visualization learning issues using an analysis technique. Integration of solid modeling into the curriculum is refined using three advanced cognitive Instructional Design training techniques. The model of Cognitive Apprenticeship is examined. The theory of Contextual Module Analysis is put into practice. The tenets of Situated Learning and importance of workplace replication are explained. The resulting document is a model for Engineering Design Graphics addressing training issues.

Learning Opportunity/Background

As engineering educators, we are responsible for the quality of education and making our students the "best-in-the-world" in the subject area's of engineering, science, technology, and mathematics. The computer and calculator have provided us with technology tools to accomplish these tasks. New hardware and software allow us to remain relevant and to put into practice the latest innovations. These technology tools motivate the learner in a different manner than in a conventional class. These tools allow us to use realistic problems and to solve them in a more sophisticated manner.

The traditional method of teaching 2-D visualization skills in engineering design graphics classes employs various techniques and student activities. These techniques and student activities are shown in Table One.

Table 1

2-D VISUALIZATION MODEL

Type	Technique	Student Activity
0>0	2-D Orthographic	Produce orthographic drawing Add missing orthographic lines
P>O	2-D Isometric Pictorial	Produce orthographic drawing Add missing orthographic lines
O>P	2-D Orthographic	Produce pictorial drawing Add missing pictorial lines
p>p	2-D Isometric Pictorial	Produce pictorial drawing

Table 1 (continued)

		Add missing pictorial lines

O=Orthographic P=Pictorial

These methods of 2-D Visualization instruction allow the learner to conceptionalize between 2-D orthographic and 2-D orthographic; 2-D pictorial and 2-D orthographic; 2-D orthographic and 2-D pictorial; and 2-D pictorial to 2-D pictorial. Each orthographic drawing is a depiction of a front, top, and right side view. Each pictorial drawing is a depiction of an isometric.

Lacking from this visualization instruction is any mention, method, or incorporation of 3-D instruction. Personal computers now have the capability of creating mathematical 3-D models. These 3-D models have databases that may be used to automate manufacturing. The solid models strength as a design tool is indispensable. Mass property analysis of a region or solid model is possible. Drawings maybe created by extracting the 2-D orthographic views using a 3-D solid model. As students are exposed to solid model visualization, 3-D to 3-D pictorial visualization instruction will become an important learning issue. Oladipupo has shown that solid modeling will improve and confer visualization skills .[15] A preliminary study conducted by Devon showed students experienced in solid modeling scored higher on the Mental Rotation Test .[18] The methods of visualization seem best derived using a 3-D model.

Analysis of Issue

Using the existing 2-D Visualization model defined in Table One, 3-D Visualization could be taught using similar techniques and student activities. Similar techniques and student activities of 3-D visualization are shown in Table Two.

Table 2

3-D VISUALIZATION MODEL

Technique Type	**Using A/AN**	**Student Activity**
S>S	3-D Solid Model	Produce solid model Add missing solid model lines
P>S	2-D Pictorial Isometric	Produce a solid model Add missing solid model lines
O>S	2-D Orthographic	Produce a solid model Add missing solid model lines
S>P	3-D Solid Model	Produce pictorial drawing Add missing pictorial lines
S>O	3-D Solid Model	Produce orthographic drawing Add missing orthographic lines

O= Orthographic P=Pictorial S=Solid Model

This method of 3-D visualization instruction would allow the learner to conceptionalize between 3-D solid model and 3-D solid model; 2-D pictorial and 3-D solid model; 2-D orthographic and 3-D solid model; 3-D solid model and 2-D pictorial, and 3-D solid model and 2-D orthographic. A computer based instructional program is being developed to test the objectives of visualization derived in Table Two. This program covers most visual examples, allows the student to be interactive in the learning, and provides immediate feedback. Using visualization techniques each solid model will be depicted from eight spatial positions in a solid model format, in six views using an orthographic format, and in six views from an isometric format. Each object will be drawn as a 2-D orthographic, 2-D pictorial isometric, and 3-D solid model. Orthographic and isometric views will be required to exhaust all visualization possibilities.

Guiding Principles in the Design

Integrated into the instructional design are models of Cognitive Apprenticeship, theories of Contextual Module Analysis, and tenets of Situated Learning. Collins and Brown have developed a model called Cognitive Apprenticeship .[3] Cognitive Apprenticeship is a model of Instructional Design. This model uses the principles of traditional apprenticeships and applies them in an environment of modern training conditions. With the use of complex and automated production systems, high levels of expertise are required of employers. Workers are required to become experts and problem solvers. This situation creates a need for present employees to become experts through forms of apprenticeships. Collins, Brown, and Newman have shown that programs using these principles have been successful, especially in basic skill instruction .[4] Cognitive apprenticeship includes eight instructional principles. Collins and Brown's principles include: context; situated learning; modeling and explaining; coaching and feedback; scaffolding and fading; articulating and reflections; exploration; and sequence. Table Three has been constructed to apply the cognitive apprenticeship model to principles of 3-D Visualization.

Table 3

COGNITIVE APPRENTICESHIP AND 3-D VISUALIZATION

- CONTEXT
  - Textbook Knowledge
    - Mechanical Drawing
    - Blueprint Reading
    - ANSI Standards
    - Computer Literacy
    - Computer Aided Design
    - 2-D Visualization & Construction
    - Orthographic Projection
    - Geometric Construction
    - Scales
    - Sketching
    - Sectioning
    - Threads
    - Fasteners
    - Dimensioning
    - Tolerancing
    - Section Views
    - Auxiliary Views

Table 3 (continued)

- Descriptive Geometry
- 3-D Visualization & Modeling
- Boolean Operation
- Design Analysis Simulation
- Parametric
- Idea Presentation

Tacit, Heuristic Knowledge

- Unwritten Rules
- Expert Testimony

SITUATED LEARNING

- Replicate the workplace
- Use benchmark hardware and software
- Check drawings for errors
- Produce error free drawing
- Construct solid models
- Analyze solid models
- Convert 3-D to 2-D
- Rapid Prototyping
- Design Team

MODELING & EXPLAINING BY DEMONSTRATION

- Develop basic size
- Define shape description
- Add annotated features
- Use short sequences
- Remove detail from initial construction

COACHING & FEEDBACK

- Provide assistance as needed
- Observe performance
- Act as resource

SCAFFOLDING & FADING

- Demonstrate difficult procedures
- Build student independence
- Individual instruction

ARTICULATION & REFLECTION

- Use sketches
- Construct models
- Build prototypes

EXPLORATION

- Encourage use of alternate methods

Table 3 (continued)

SEQUENCE
Begin with simple
End with complex

Contextual Module Analysis

Contextual Module Analysis involves an analysis of information to be learned. According to Tennyson, Elmore, and Snyder this analysis of information defines the critical features of information and relationships of organizations, and task analysis .[23] Organizations may be superordinate or subordinate. A problem analysis identifies principle concepts that should be employed. Problem situations are identified by analyzing principle associations of concepts. Application using the contextual module analysis approach involves five steps. These steps include: define the context, define the complex problems, analyze the problems, organize information into clusters, and sequence clusters into instructional components. Application of contextual module analysis to 3-D visualization is shown in Table Four.

Table 4

CONTEXTUAL MODULE ANALYSIS AND 3-D VISUALIZATION

DEFINE THE CONTEXT

Using views drawn in 2-D orthographic, 2-D pictorial isometric, and 3-D solid model, complete 3-D Visualization exercises.

DEFINE THE COMPLEX PROBLEMS

Build models that contain features of normal surfaces, inclined surfaces, oblique surfaces, and cylindrical surfaces.

ANALYZE THE PROBLEMS

Choose primitives including: box, cylinder, cone, torus, sphere, and triangle. Perform Boolean operations of union, substract and intersect. Construct solid models.

ORGANIZE INFORMATION IN CLUSTERS

This step states each problem and corresponding principle concepts.

Problems	**Principle Concepts**
Solid Model Visualization	Normal Surfaces Inclined Surfaces Oblique Surfaces Cylindrical Surfaces

Table 4 (continued)

SEQUENCE CLUSTERS INTO INSTRUCTIONAL COMPONENTS

This step states problem situations and principle association of concepts

Problem Situations	Principle Association of Concepts
Geometric construction	Geometric construction
Pictorial isometric	Geometric construction Pictorial isometric
Normal surface	Geometric construction Normal orthographic
Inclined surface	Geometric construction Normal orthographic Inclined orthographic
Oblique surface	Geometric construction Normal orthographic Inclined orthographic Oblique orthographic
Cylindrical surface	Geometric construction Normal orthographic Inclined orthographic Oblique orthographic Cylindrical surface
Section	Geometric construction Normal orthographic Inclined orthographic Oblique orthographic Section
Auxiliaries	Geometric construction Normal orthographic Inclined orthographic Oblique orthographic Section Auxiliaries
Descriptive geometric	Geometric construction Descriptive geometric

This content analysis defines the critical features of information and relationships. This analysis is necessary to select specific models for visualization. The large number of possible models increases the analysis importance. These models are used in the computer-based instruction module.

Situated Learning

Situated Learning involves both the nature of learning and the design of learning experiences. According to McLellan the goal of situated learning or situated cognition is to optimize the design of learning experiences. [14] The main feature of this model is an analysis of context. She states that this context maybe an actual work setting, a realistic artificial work environment, or context in video or multimedia programs .14 The use of technology will expand the situated learning model. Video camcorders, audio recorders, and computers may be used to compare expert and novice performance during the reflection and coaching sequence.

The implementation of the situated learning model involves creating a realistic artificial work environment. This is accomplished by having students complete a number of job assignments. These assignments are the drawings of typical work pieces or piece parts found in many manufacturing corporations. Using the computer as a tool, students will complete mechanical drawings that could be used for production purposes. These drawings will be made to American National Standard Institute (ANSI) standards. Principles of mechanical drawing and blueprint reading will be put to use through drawing production. An understanding of pictorial, orthographic, and solid modeling techniques will be required. Basic computing, DOS, Windows, and CAD skills are required. Assignments are submitted in a near-perfect format. Students are allowed to correct errors before submitting final assignments.

Management of the situated learning model requires the instructor to treat students at the university as novice or just plain folk. Teaching strategy may need to be altered to satisfy the needs of these two different audiences. Causal stories comprise portions of the instruction as well as occasional laws. This model requires thinking and problem solving skills. Stories and narratives play an important role in the transfer of information and discovery. These stories provide a structure for remembering and understanding what was learned according to McLellan. *[4] The situated learning model components include apprenticeship, collaboration, reflection, coaching, multiple practice, and articulation of learning skill. Application of situated learning to 3-D visualization is defined in Table Five.

Table 5

Situated Learning & 3-D Visualization

Steps	**Novice** or Student	Just Plain Folk	Expert
Apprenticeship	Reading Assignments Homework Reference	Reading Assignments, Homework Reference	Lecture and Demonstration Narrative Stories Reference
Collaboration	First Drawing Draft	First Drawing Draft	
Reflection			Correct First Drawing Draft
Coaching			On the Spot Assistance

Table 5 (continued)

Multiple Practice	Correct First Draft Complete Additional Drawings	Correct First Draft Complete Additional Drawings
Articulation of Learning Skills	Design Project	Design Project

Collins, and Duguid have defined the model of situated cognition as influenced by activities, context and culture, and contextually situated .[3] They conceptualized the population as novice or student, expert, and just plain folks. The student or novice reasons with laws, concepts and experiences. The expert reasons with causal models requiring thinking and problem solving skills. Just plain folk reason with causal stories and concepts requiring thinking and problem solving skills. Application of the situated learning model is defined in Table Six.

Table 6

Application of Situated Learning Model

	Reason With	**Engaged in Activities**	**Require**
Novice or Student	Use ANSI Standards Do things by the book		
Just Plain Folk	Describe the Problem	Situated in culture in which they work	Models, Mockups, Multimedia
Expert	Simulate the Problem	Situated in culture in which they work	Models, Mockups, Multimedia

They further defined the expert and just plain folk as engaged in activities in which they work. Just plain folk were classified as cognitive apprentices.

Conclusion

You can adopt computed aided design as the tool to produce mechanical drawings. We must consider adopting solid modeling as the next tool for design and analysis. The importance of the solid model as a learning tool for visualization cannot be overemphasized. Solid modeling will simplify the understanding of spatial visualization.

As an institution of higher learning we must provide a scholarly environment and relevant instruction. We must be a service to the employers that hire our graduates least they abandon our service and form instruction to suit their immediate needs.

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