Defining Concepts for an Engineering Graphics Concept Inventory: A Delphi Study

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Abstract

In 2010 the authors were awarded a grant from the National Science Foundation to conduct a Delphi study as a first step in defining a concept inventory for engineering graphics. Graphic topics were identified, defined, and illustrated for a panel of experts to evaluate. The first two rounds of the Delphi study helped to eliminate some topics, add missing topics, and identify emerging concepts. This paper presents the twelve concept themes currently being considered for the Engineering Graphics Concept Inventory.

Introduction

A concept inventory is an instrument that helps faculty identify the concepts that their students do not understand and decide which misconceptions are the most prevalent. In addition, concept inventories can help define important fundamental topics for instruction and learning. The goal for this project was to develop an instrument which measures students' conceptual knowledge of graphic communication and enable faculty at all levels to assess student understanding of fundamental concepts in graphics, to evaluate the effectiveness of the courses they teach, and to make adjustments as necessary. (Sadowski & Sorby, 2012) The method used was a Delphi study, which is a consensus-building, forecasting technique that has been used by organizations, agencies, and corporations for making predictions and setting agendas. A Delphi study typically consists of three to four rounds, conducted with a panel of experts, to reach consensus on defining the important elements related to the questions posed. A Delphi study also lends itself to reaching consensus without a need for face-to-face meetings among panel members, making the study relatively easy to implement, especially for a panel with broad geographic representation among its members. (Sadowski & Sorby 2013)

Project Activities.

- An initial brainstorming session with a small group of faculty leaders in graphics education was held in conjunction with the 66th midyear meeting in Galveston, Texas. This session resulted in a list of topics that could be considered for the Graphics Concept Inventory (CI).
- A second meeting was held in conjunction with the ASEE annual meeting in Vancouver (June 2012) to examine the list of topics produced at the first meeting and to assign the topics to members for illustration and definition purposes.
- A third meeting was held in conjunction with the ASEE annual conference in Atlanta in June 2013. The final slides were examined and put into categories using a thematic approach.
- The panelists for the Delphi included experts from four-year universities, community colleges, high schools, and industry. (Sadowski & Sorby, 2013)
- Round I included 80 topics complete with graphics and definitions and 40 panelists who were asked to gage the importance of each topic, provide comments as needed, and suggest topics that might be missing. At the end of Round I, 49 topics were moved forward, 31 topics were dropped, and 6 topics were added for a total of 55.
- The results from Round I were used to create the instrument for Round II. Round II included 55 topics and 30 panelists who were again asked to gage the importance of each topic, provide comments as needed, and suggest topics that might be missing.
- The results from Round II were tabulated to create the themes for Round III.

Round III

The results from Round II included many thoughtful and incisive comments and suggestions. The 55 individual topics began to coalesce around a series of larger concepts. While some topics were dropped from this round, many were incorporated into 12 concepts that emerged from the data and the comments.

Emerging Concepts

Visualizing in 2D: Understanding the relationship of orthogonal views of geometry.

Aspects of this concept include:

Edge View	Point View
Normal	Non-normal
Foreshortening	True Shape and True Size
View Alignment	View Direction

Mapping between 2D and 3D: Representing, converting, creating, and interpreting data from 2D to 3D and 3D to 2D.

Aspects of mapping between 2D and 3D include:

Conversion	Interpretation
Creation	Criteria for Representation

Object Representation – Visual Depiction: Representing, converting, creating, and interpreting data from 2D to 3D and 3D to 2D.

Object representation elements would include:

Shape	Contour
Lighting	Outline
Shading	

Engineering Methodologies for Object Representation: Representing the 3D world using 2D visual methods using engineering graphic techniques.

Engineering methodologies for engineering graphic techniques include:

Isometric	Oblique
Exploded	Perspective
Assembly	Storyboards

Planar Graphical Elements: The ability to pass a plane in space that serves a particular function.

Planar graphical elements include:

Reference Planes	Cutting Planes
Datum Planes	Projection Planes

Sectional Views: This subset of Planar Graphical Elements is the establishment of a plane for the purpose of showing interior and exterior features of an object.

Sectional view elements include:

Full Sections	Half Sections
Removed Sections	Revolved Sections
Offset Sections	Broken-out Sections

Projection Theory: Projections are created by viewing an object with a transparent plane placed between the observer and the object. The image of the object is projected onto that imaginary plane, defined as the plane of projection. A two-dimensional representation, or view, of the object is the result.

Projection aspects would include:

Line of Sight	Plane of Projection
Auxiliary Views	True Length
Edge View	Point View
Inclined Surfaces	

Parallel Projection Methodologies: Graphically represent 3D objects in a 2D medium based on a line of sight and a plane of projection. The object is positioned at infinity and viewed from multiple points on an imaginary line parallel to the object.

Parallel projection methodologies:

Orthogonal	Axonometric
Oblique	Isometric

Drawing Conventions: Conventional methods used to define and express a graphical description.

Drawing convention elements would include:

Annotations and Notes	Callouts
Concentricity	Labeling
Line Types	Line Precedence

Dimensioning: The process of providing an accurate, clear, complete, and readable description of an object. Dimensions provide the information needed to specify size, form, orientation, and location of geometric features and components of an object.

Dimensioning aspects include:

Shape Description	Size Description
Dimension Placement	Location Description

Solid Modeling Constructs: A consistent set of principles for mathematical and computer modeling of three-dimensional solids, which supports the creation, exchange, visualization, animation, interrogation, and annotation of digital models of physical objects. A solid model is a digital representation of the geometry of an existing or envisioned physical object ensuring that all surfaces meet properly and that the object is geometrically correct allowing for interference checking. It also simulates an object internally and externally and can be sectioned to reveal internal features.

Solid modeling constructs include:

Extruding	Boolean
Lofting	Sweeping
Revolving	Features

Scale and Similarity: The specified ratio of reduction and enlargement using a unit of measure that is a standardized quantity. The constant ratio is called the similarity ratio or similarity factor. Scale involves the proportional increase or decrease of an object/model drawing, which preserves the shape of the object but increases or decreases all distances by a constant ratio.

Scale and similarity aspects include:

Ratio	Congruence

Conclusions

A dictionary definition of a concept is *an idea of something formed by mentally combining all its characteristics or particulars: a construct* (2014). A major aspect of this project has been to break engineering graphics into its many and varied aspects, to look at them individually, and then bring some of them back together as unified and important concepts. The concepts presented here are not final; the expert panelists still have work to do. However, we have made considerable strides in tackling this effort.

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