Development of CAD-Related Items for a Concept Inventory for Engineering Graphics

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Abstract

This paper describes the initial development of a concept inventory for Engineering Graphics. As instructional methods continue to evolve in the area of graphics, there is a need for a concept inventory instrument that is able to measure the students' misconceptions of important graphical concepts. In a 2014 Delphi study, CAD was identified as an important component of the graphics curriculum to be included in the concept inventory. There have been unanticipated challenges in the creation of multiple-choice items designed to assess the understanding of the concepts in the CAD construct. This paper is a work-in-progress describing the evolution of possible CAD items. Details documenting the evolution of a representative item will be highlighted in this paper.

Keywords: CAD, computer aided design, concept inventory, engineering graphics, Delphi Technique

Introduction

Teaching methods in engineering graphics are ever changing; as technology advances, so do the means by which engineering students learn this form of communication. Often, instruction is centered on methods of creating graphics instead of the underlying fundamental concepts. While it is important to stay relevant in regard to current technologies, it is also important to keep in context the concepts that serve as an underpinning for the methods being employed. It is generally agreed that students should have a certain level of proficiency in standard practices upon completion of a graphics course of study. However, there is no consensus regarding the topics considered to be the fundamental concepts. This lack of consensus can lead to nonconformities in educational practices, and may decrease effectiveness in graphics education.

Background

Concept Inventories are assessment instruments used to identify understanding or misconceptions regarding a set of related conceptual ideas. Misconceptions are often deeply rooted beliefs, and can be problematic for instruction. To address these misconceptions, the constructs that students are having difficulty with first need to be identified. In a previous project, a Delphi Study was conducted to help identify core topics in engineering graphics (Sadowski & Sorby, 2014). The Delphi is a consensus building, forecasting technique typically consisting of three to four rounds, using 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). Delphi studies have been used extensively in educational development projects (e.g., Clark & Scales, 1999) including concept inventory development (Streveler, et al. 2011). The Delphi technique typically encourages panelists to include comments as they make their ratings, resulting in a rich written conversation about choices made, possible options, and changes that might be made in future rounds (Sadowski & Sorby, 2015).

We selected the assessment triangle model proposed by Pellagrino (Pellagrino, et al. 2001) as our theoretical framework for CI development. This model has been recommended by the National Research Council as a framework for creating state-of-the-art assessment instruments and consists of three interrelated elements – cognition, observation, and interpretation. More information about the assessment triangle and its use in concept inventory development can be found has been reported by Streveler (Streveler, et al. 2011).

Process to Date

The initial solicitation of topics took place at a workshop consisting of graphics professionals and resulted in a total of 120 unique topics. From this, the list was consolidated into 80. An expert panel of industry representatives, high school teachers, community college instructors, and university faculty was convened for the three rounds of the Delphi study. Round 1 had a panel of 40 experts and moved 58 of the 80 topics forward. Round 2 had a panel of 31 and coalesced the 58 topics into 12 major concepts. With this manageable number of concepts to work with, constructs to describe the topics could be formed. These constructs would serve as the basis for instrument item development. The third and final round of the Delphi had 31 panelists, who refined the list to a final 10 concepts with a total of 37 identified constructs. Table 1 includes the final list of concepts with their importance as rated by the panelists on a 1 – 5 scale with 5.00 being very important. (Sadowski & Sorby, 2015)

Table 1: Concepts by Importance as Identified by Delphi Panel of Experts

Visualizing in 2D and 3D	4.81	Projection Theory	4.47
Sectional Views	4.63	Mapping between 2D and 3D	4.45
Dimensioning	4.60	Methodologies for Object Representation	4.29
Drawing Conventions	4.50	Parallel Projection Methodologies	4.27
Planar Graphical Elements	4.48	Solid Modeling Constructs	4.27

In December 2014 a survey was sent to the Delphi panelists and members of the EDGD listserv as well as to some graduate students who routinely grade and assess graphics leaning among first-year engineering students. The survey included the ten graphics concepts and the 37 constructs that had been identified through the Delphi study. Eighty professionals participated and were asked to rate the difficulty a typical student might have understanding each of the proposed constructs. (1=easy/5=difficult)

Initially seven CAD constructs were included in the Delphi study: Blending, Boolean, Extruding, Lofting, Revolving, Scaling, and Sweeping. At the conclusion of the Delphi only Sweeping, Revolving, Extrusion, and Features were retained. While Solid Modeling as a concept was rated of high importance (4.27/5.00) by the Delphi panel, the difficulty of the four constructs was rated low between 2.39 – 3.70 on a 5.00 scale. (Table 2)

Table 2: Difficulty and Importance Ratings of CAD Topics and Concepts

Solid Modeling Constructs	**4.27 importance**
Sweeping	3.70 difficulty
Revolving	2.98 difficulty
Features	2.95 difficulty
Extrusion	2.39 difficulty

With the concepts identified, work on item development began. Discussions between the project principals provided collective guidance for the drafting of pilot questions. These questions were designed to address each of the concepts individually whenever possible. An open-ended format was selected for the pilot questions in order to better observe the misconceptions held by average students. The participants were beginning graphics students at three different universities. The questions generally required participants to provide a response in the form of a sketch.

Administering open-ended questions generated formative feedback in two areas. The first was that subjects' answers could provide information on potential distractors, as patterns in the responses could reveal tendencies in student misconceptions. The second area was related to item structure and framing. Subjects were encouraged to comment on the format of the questions, making note of interpretations and errors. Test packets were administered in the pilot study in a uniform fashion. Pilot responses from all institutions were collected and the results were aggregated. The responses were coded by the researchers to identify trends. With the data from the pilot study coded, work could begin on drafting potential distractors.

Herein lies the problem with the Solid Modeling (or CAD) Constructs topic. Pilot Items were presented in what was intended to be an appropriate format for participants to provide open-ended, non-software-specific, responses. Figure 1 shows an example item from the pilot study. Participants were asked to describe in general terms the creation of the provided object if using a CAD system.

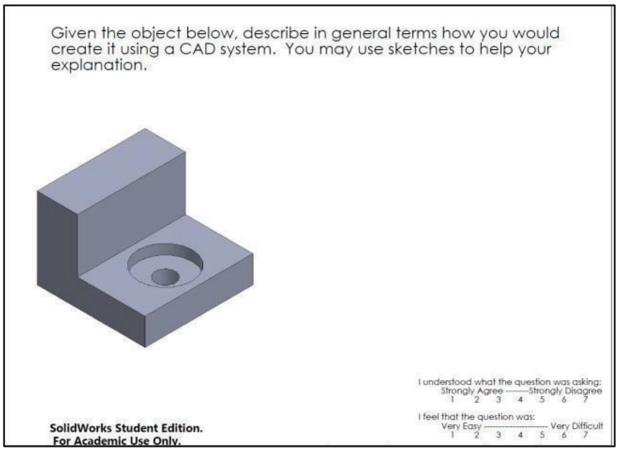

Figure 1: Example Open Ended Pilot Study Item

Figures 2 through 5 are examples of typical student responses to the sample item. The high degree of variation in these responses could be problematic when identifying distractors for concepts. It was observed that there was much less sketching in the responses than anticipated. Figures 2, 3, and 5 show additive approaches to construction, while Figure 4 shows a subtractive approach. Figure 5 provides a more terse description than the others, while still providing an arguably correct description. When considering the constructs that applied to CAD items, additional questions arose among the researchers on how to make inferences about students' work. What should be done when the answers differ from the proposed solution? How does one assess design intent in the creation of the object? Or should design intent even be considered if the resulting geometry of the model is visually correct? What makes one response more or less valid than another? Further, are the difficulties students demonstrate cited by instructors associated with specific software commands rather than the fundamental concepts? Are the CAD concepts, as *concepts,* really misunderstood by students?

Initial review resulted in the decision to set aside the CAD problems for later evaluation, with the intent that additional review of other items in the pilot test would provide experience in the coding of items and distractor generation. Later attempts by the team to assess the students' answers for the CAD problems continued to prove unproductive, and only yielded questionable results for potential distractors.

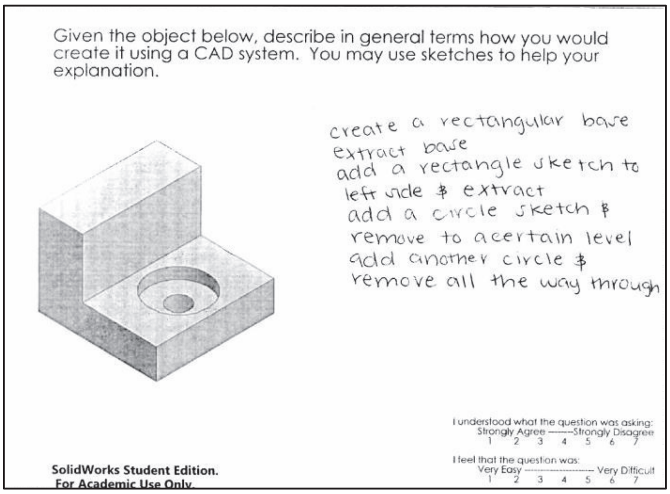

Figure 2: Sample Open Ended Student Response.

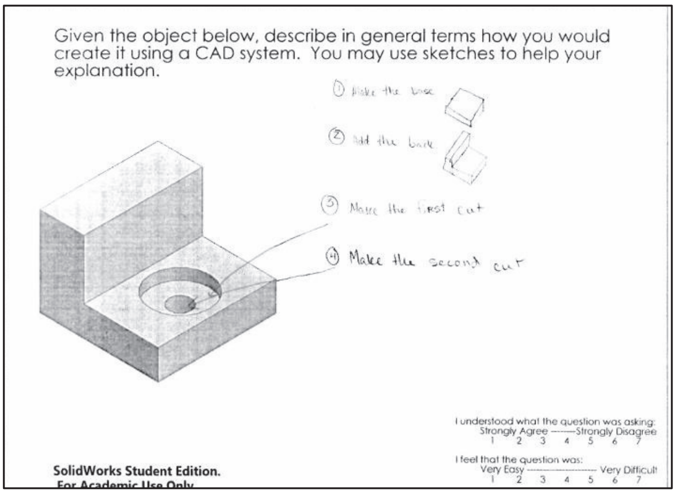

Figure 3: Sample Open Ended Student Response

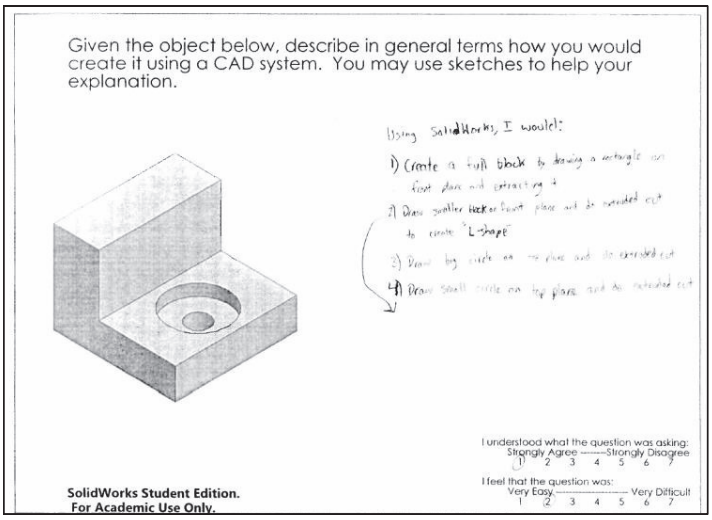

Figure 4: Sample Open Ended Student Response

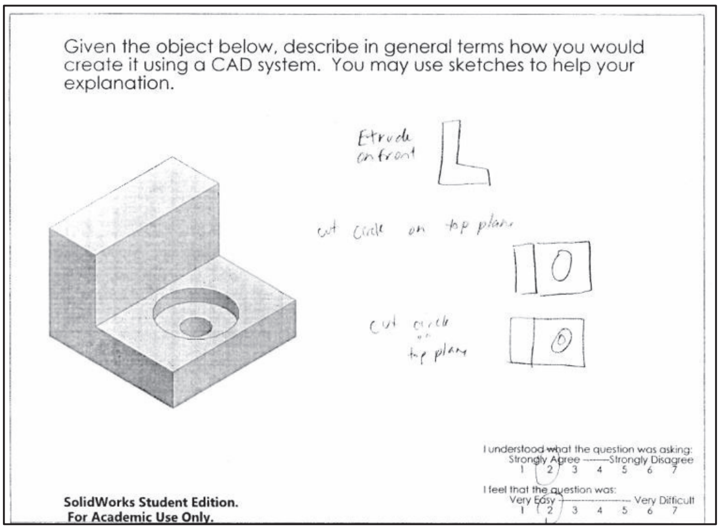

Figure 5: Sample Open Ended Student Response

Current Status

The research team is currently making revisions to the items that will be included in a draft version of a multiple choice concept inventory instrument. Once the distractors have been selected for the remaining items, they will be created electronically and consistently formatted. However, this is not the case with the creation of the CAD items whose development remains at a standstill. Results from the Delphi study indicated that the topic of Solid Modeling and CAD were considered an important part of the graphics curriculum; yet, it is proving to be increasingly difficult for the research team to make progress with the creation of items to measure these constructs. Further, it is not clear that CAD *concepts* are misunderstood and thus should be included in a concept inventory that results from this project.

Conclusions

The work in the development of a concept inventory for engineering graphics has yielded valuable insights thus far. Items addressing the topic of Solid Modeling/CAD Constructs tended to generate a range of unexpected responses. Unsuccessful attempts at consistent response coding and meaningful development of distractor items resulted in the idea of seeking further input from graphics experts. It is the research team's intent to reach out to the graphics community for more feedback in the area of CAD constructs. While Solid Modeling/CAD was rated as very important by the Delphi panel, most of the individual constructs were not rated as difficult for students to understand. A possibility for CAD constructs to have a separate concept inventory has been discussed within the team. Evaluations on whether to pursue this option, or any alternative strategy are welcomed by the research team.

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