Update on a Delphi Study for Developing a Concept Inventory for Engineering Design Graphics

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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. The rationale for the need for a concept inventory in engineering graphics is that unlike many other foundational subjects in engineering such as statics, dynamics, or strength of materials, engineering graphics instruction has changed significantly over the past century, and, in this climate, it is important that graphics educators keep sight of the fundamentals in graphics education. The primary reason for the change in graphics education over the past few decades is the development of new graphical tools and methods at an increasingly rapid pace. In an ideal world, educators should not rush to change for the sake of the new tools, ignoring fundamental concepts along the way. Unfortunately, there is little agreement about what constitutes the fundamentals in graphics education. In other science and engineering fields, such as physics, mathematics, statistics, and engineering science, concept inventories have been developed in recent years to define the fundamental concepts in those disciplines. The concept inventories provide educators with a standardized instrument that they can use to help design their courses and to determine if their students understand the fundamental concepts. As a first step in the development of a nationally normed concept inventory for engineering graphics, a Delphi study is being conducted to define the fundamental concepts. The concept inventory itself will be developed as part of the next steps. This paper describes the Delphi method and outlines progress to date on the project.

Introduction

Throughout its history, engineering graphics has embraced the "tool of the day" migrating from hand-drafting tools to 2-D and, finally, to fully integrated 3-D design systems. Graphics educators have discussed the benefits of one CAD package versus another, debated the need for

inclusion of topics such as traditional descriptive geometry, and focused on industry needs in designing their graphics courses. However, rarely, have they discussed the foundational concepts that should be included in a graphics course at any level. This Delphi study seeks to define these foundational concepts so that educators can design courses to meet the needs of today's students and the ever changing tools and graphics techniques.

Need for a Concept Inventory in Engineering Graphics

Engineering graphics is one of the highest enrollment courses in all of the STEM fields. Graphics remains a requirement for many engineering and technology disciplines. Common first-year engineering programs including Virginia Tech, Purdue, Texas A&M, and Michigan Tech contain a strong graphics component. At Purdue, College of Technology professors teach engineering graphics courses to freshman engineers, as well as engineering technology students. Graphics is also taught in pre-engineering and in engineering technology programs at community colleges and high schools. High school graphics is often taught primarily for students who intend to major in a STEM field after graduation. No consensus regarding optimal content for graphics courses exists, resulting in a large degree of variation among courses across the country.

A concept inventory for engineering graphics would identify "core" graphics topics so courses could be designed around this core. A concept inventory would lead to a better connection between all levels of graphics courses ensuring that high school and community college courses map to the expectations of university-level graphics courses. A concept inventory would also 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.

Delphi Technique

A Delphi study is a consensus-building, forecasting technique that has been used by organizations, agencies, and corporations for making predictions and setting agendas. Although this technique was developed in the "business world," a number of educational leaders including Clark & Scales (1999), Volk (1993), and Zargari, Campbell, & Savage (1995) have suggested its use in the design of curricula and programs. A Delphi study typically consists of three to four rounds, conducted with a panel of experts, to reach consensus on defining the important elements of a curriculum. 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.

Project Activities

Upon notification of award by the National Science Foundation, the project team has been implementing the planning and organizational activities required to conduct the Delphi study. The following activities have been accomplished to date:

- 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. Topics in graphics education were listed and put into categories with no attempt to distinguish between "topics" and "fundamental concepts." The idea was to be as inclusive as possible with "weeding out" to be conducted in later stages of the Delphi study.
- 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 purposes.
- Participants created 20-40 slides depicting the topics or concepts that had been assigned to them.
- A third meeting was conducted in conjunction with the ASEE annual conference in Atlanta in June 2013. The final slides were examined and put into categories based on conceptual "themes."

With the topics/concept slides completed, the following activities were planned:

- The concept/topic slides will be incorporated into the electronic Delphi instrument with the Delphi study commencing in August 2013. Invitations for participation in the Delphi survey will purposefully include university, community college, high school, and industry leaders.
- In the first round of the Delphi study, participants will answer two questions regarding each item:

  1) Is this a concept or a topic?

  2) Is it essential?

  Based on the results from this round, we expect to eliminate a significant number of the items.
- Further rounds of the Delphi study will be conducted as needed to winnow the topics to a remaining few fundamental concepts. After round one, we will ask participants:

  1) Is this an important/fundamental concept?

  2) Is this a concept where there are significant student misconceptions?

Adaptive Comparative Judgment (ACJ)

In the process of conducting the activities associated with the Delphi study, the authors were

introduced to the adaptive comparative judgment technique for reaching consensus regarding the "preference" of items from a list of many. Through this technique, participants view two pairs of items and make a judgment about which is more important. At any given time, the participant only sees two items; however, s/he may see the same item more than once. Each participant will not see all of the items and will make judgments based on the two presented at any given time. Depending on the number of participants and the number of items, each person may rate 20-40 pairs during a session. Since they are comparing only two items at a time, the process is not overly time-consuming.

Adaptive comparative judgment is used for consensus-building among disparate groups, which is also the key goal of the Delphi study. Typically, the correlation coefficient for the consensus on the ACJ is around 0.9, meaning that there is a high degree of agreement for the final results. For this reason, the authors wondered could the ACJ replace the Delphi study for educational consensus-building. Could the adaptive comparative judgment be used to augment the Delphi study to arrive at consensus much more quickly?

The decision was made to conduct the ACJ technique simultaneously with the Delphi study to answer the following questions:

1) Do we achieve essentially the "same" consensus among the group members through the two different techniques?

2) Is there an advantage in terms of implementation between the two methods? (i.e., is one method or the other easier to employ)

3) How do participants feel about the two methods, (i.e., do they "prefer" one method over the other)

Depending on the results from this research, we could identify an exciting new approach for achieving consensus around curriculum design while simultaneously, identifying the critical concepts for Engineering Graphics.

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