A Proposal for a Nationally Normed Engineering Graphics Concepts and Skills Test

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Abstract

The sciences and physics in particular have found that nationally normed tests allow educational researchers to measure the effect of changes in methodology and technology. In particular, physics uses the Force Concept Inventory. and the Mechanics Baseline test for testing students in physics mechanics. Another test on the concepts of electricity and magnetism has also been created. These are used and cited frequently in the physics education literature. In Engineering Graphics, we have the Purdue Visualization Tests, Young and Sorby's placement exam, and some now outdated tests. The question is, 'Does engineering education need such a test?' and 'What form should it take?'. Do we want to measure mastery of concepts (and what are they?), measure sketching skills, measure visualization skills, reading working drawings, etc. This paper will lay the background for a discussion to be held as part of the session at ASEE 2001 and, if this is accepted by the Engineering Design Graphics Division (EDGD) as a worthy task, such discussions and work on creation of a test or tests will continue over the next couple of years.

Introduction and Rationale

There is a need for Engineering Graphics faculty who are doing educational research to have a test or a set of tests to measure the effectiveness of changes in methodology and technology. Background work done with surveys of engineers in industry indicates that there are certain graphics topics that are needed by all engineers. Can the EDGD create such a test or tests that would both measure the effectiveness of changes and insure that engineers have sufficient graphics to be effective in their jobs?

Background from Physics

The Physics education research community now has several nationally normed tests. These tests allow the physics education researchers to make changes to methodology and technology and determine the results on student learning. The first paper in the series we reviewed was by Halloun and Hestenes at Arizona State [1]. This paper dealt with the creation of a test that measured whether students had the correct concepts about physics mechanics i.e. Newton's Laws. This test was created by establishing questions about Newtonian concepts and giving them to faculty who understood and used the concepts. Once the series of questions was established, these same questions were given to students before they had taken college physics. Their misconceptions were gathered as alternative answers to the questions.

The test was then given to groups of students both as a pre-test and a post-test for college physics. What the researchers found was that the misconceptions were pretty well established in the students' minds based on their life experiences and that beginning physics courses did not do much to change the misconceptions. In other words, students were leaving introductory physics as non-Newtonian thinkers.

Additional research by Hestenes[2,3] established that there are concepts or misconceptions established early that can be measured by the type of test described above. There are also a series of topics that can be measured only after a student has taken the first course in physics. From the earlier research, two new tests were created. One was called the Force Concepts Inventory which tested for Newtonian misconceptions and is now being used as a pre- and post-test. At the same time, a companion paper established the Mechanics Baseline Inventory of knowledge that should have been learned in the first physics course[4].

The Physics Research Community has found these tests to be very useful in their research into active learning, experiential learning, and the importance of designing experiments to establish principles. The Community has now created a Concepts of Electricity and Magnetism test for the second course in Physics.

This type of research raises some questions for us in the Engineering Graphics (EG) community. Do students come to us with misconceptions about graphical communication or do they simply have no knowledge at all? Are there some skills or knowledge that can be measured by a pre- and post-test strategy similar to the FCI? We have been using the Purdue Visualization[5] test to determine whether students improve their visualization skills in an EG course. Are there other such skills or knowledge that the students may have about graphics? Should we administer a comprehensive test before and after EG courses simply to establish that the students knew nothing (well, almost nothing) when they came to us and that they leave with a set of skills and knowledge that will be critical to their professional development and career?

National Graphics Tests

Most recently, graphics educators have concentrated on testing students' abilities to visualize through a number of instruments ranging from spatial visualization through mental rotations. One of the most popular visualization tests is the Purdue Spatial Visualization Test: Rotation. With this test, students are given an object and are shown a rotation of that object. They then must view a second object and determine its view if it were rotated in the same way as the first object. The test is composed of 30 questions and students are given 20 minutes to answer all 30 questions. Although some researchers have reported this test as a significant predictor of success in an engineering graphics course[6], it is limited to testing only one skill essential to a successful engineering graphics curriculum. Other work, reported by Young and Sorby[7], includes fifty multiple choice questions covering nine skills.

The drawing portion of the Cooperative Industrial Arts Tests proved to be a valuable instrument for evaluation of basic graphics instruction[8]. This test is a multiple choice test of fifty questions that cover pictorial shape description, non-pictorial shape description, size description, engineering drawing, line precedence, equipment, materials, reproduction methods, and industrial applications. Students are given 35 minutes to complete the test. The test, which has been used on a nationwide basis, publishes norms tables which show the percentile ranks and the stanines for each form of the test so that students can be compared against the norms group. At the time, 1975, it was the only test for graphics recognized by the Mental Measurements Yearbook. Although this test covers all of the basic concepts with regard to instrument drawing, it is rather old and does not conform to the latest standards with regard to dimensioning practice or GD & T. Furthermore, it does not contain any material regarding CAD or Solid Modeling, which are extremely important.

The National Occupational Competency Testing Institute (NOCTI)[9,10] has developed competency exams for various occupations. These exams were designed to ensure the competency level of students who complete a program and, in industry, to measure entry level skills in prospective employees (NOCTI./student). The exams are administered in two parts, a written assessment and a performance assessment. For example, the Technical Drafting written test contains 198 multiple choice questions and covers preparation to draw, basic drawing & dimensioning skills, geometric construction, applied mathematics, shop processes, interpretation of working drawings, computer drawings, 3-D solid modeling, design principles, and descriptive geometry. The performance test, which assesses a student's skills in applying the various graphics concepts, takes five hours. Other written and performance assessment tests are available in General Drafting and Design, Architectural Drafting, and CAD/CAM. All have similar formats with varying numbers of multiple choice questions in the written assessment. The possibility exists that parts of these exams (both the written assessment and the performance assessment) could be used for our specific needs in a national norms engineering graphics test with NOCTI handling the administrative details; however, this has yet to be fully explored.

Items to Consider (Table 1)

The first column includes all of the items listed by Crittenden in his survey of topics included in graphics tests collected from programs across the country[11]. The second column is based on a survey by Barr in his proposal for developing an EDG curriculum for the 21st century[12]. His survey ranked on a 1 to 5 scale (5-very important, 3-somewhat important, 1-not important at all) many of the same topics listed by Crittenden. The third column uses data from the study by Meyers of EG curricula in major engineering colleges; thirteen curricula were examined[13]. If a topic were included in six of the curricula it was considered significant. The column labeled "INDUSTRY" is based upon a survey conducted by Ohio State faculty in 1997 and reported in 1998[14]. Engineering graduates, 5 years or less since graduation, were asked to rate topics on *Preparation* and *Importance on the Job*. Responses totaled 134; a similar survey was conducted in 1992, and the researchers looked for changes in importance and quality of preparation. *Importance on the Job* was rated 1-5, as in Barr's survey, and this value is listed in the INDUSTRY column. Again, a value of 3 was used as the criterion for inclusion in testing.

Taxonomy of Learning

There are several taxonomies of learning available; the authors have chosen Bloom's because it is widely known and appears applicable[15]. It includes six levels of learning: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. Competence in graphics requires at least an understanding of concepts (*Knowledge)* and often the ability to demonstrate skill in the creation of useful engineering documents (*Application)*. Based on the works of the researchers cited here, the authors believe that the topics marked with an "X" are worth considering for testing. All of these skills listed below in the table can be tested using the NOCTI test that is discussed above.

TABLE 1: TOPICS FOR TESTING COMPETENCE

CRITTENDEN	BARR	MEYERS	INDUSTRY	*KNOWLEDGE*	*APPLICATION*
Descriptive Geometry	2.25/5	5/13	NR		
Developments	NR	NR	NR		
Dimensioning	3.63	12/13	3.1/5	X	X
Drafting Skills	1.81	4/13	NR		
Geometric Construction	2.25*	NR	NR		
Geometry	2.25*	5/13	NR		
Graphing	2.63	6/13	NR	X	X
Intersections	2.25*	6/13*	NR		
Kinematics	NR	NR	NR		
Lettering	1.75	NR	NR		
Mathematics	2.7-2.8	5/13	2.5		
O. P. Theory	3.69	12/13	NR	X	X
Reading Drawings	NR	10/13	3.9	X	
Scales	NR	NR	NR	X	
Sectional Views	3.50	12/13	3.1	X	X
Sketching	4.38	13/13	3.4		X
Software Use	4.4*	13/13	3.1		X
Solid Modeling	4.4	13/13	3.1		X
Threads & Fasteners	3.00	5/13	NR	X	
Tolerances	3.00	6/13	2.7	X	X
Visualization	5.00	12/13	3.6		X

NR - Not Rated in this study * Not rated by this nomenclature - rating for similar topic supplied

Organization for Discussion

Is there need for such a test?
What topics beside visualization should be included in the tests?
- Multiview to Isometric, Isometric to Multiview
- Sections
- Solid modeling
- Use of CADD (just a tool?)
- Sketching
- Dimensioning and tolerances
- Reading working drawings
- Symbols – electrical, piping

Is there a common set of graphics concepts?
Are we simply talking about skills?
At what level should the different skills be tested?
Assuming that the EDGD wants to do this, how should we organize?
Should we seek funding from NSF or industry?
Where will work take place?
Where will results be reported?
- ASEE
- EDGD Mid-Year Meetings
- Journal of Engineering Education
- Amer. Society Of Higher Education
- Society Journals and Publications

References

1. Halloun, I. & Hestenes, D., The Initial Knowledge State of College Physics Students, *American Journal of Physics,* November, 1985, 1043-1055.

2. Hestenes, D., Wells, M., & Swackhamer, G., Force Concept Inventory, *The Physics Teacher*, March, 1992, 141-158.

3. Hestenes, D. & Halloun. I., Interpreting the Force Concept Inventory, *The Physics Teacher*, August, 1995, 502-506.

4. Hestenes, D. & Wells, M., A Mechanics Baseline Test, *The Physics Teacher,* March, 1992, 159-166.

5. Guay, R. B., *Purdue Spatial Visualization Test: Rotations,* Purdue Research Foundation, West Lafayette, IN, 1977.

6. Gimmestad, B. J., Gender Differences in Spatial Visualization and Predictors of Success in an Engineering Design Course, *Proceedings of the National Conference on Women in Mathematics and the Sciences,* St. Cloud, MN, Sept. 1990, 133-136.

7. Young, M. F. & Sorby, S.A., A Visualization-Based Placement Exam for Engineering Graphics, *Proceedings of the 52nd Annual Mid-Year Meeting of the Engineering Design Graphics Division of ASEE*, October, 1997, 61-78.

8. Croft, F.M. & Goss, L.D., Evaluation of Innovative Basic Graphics Instruction, presented at the Annual Conference of the American Society for Engineering Education, June 1975.

9. URL: **http://www.nocti.org/student**

10. URL: **http://www.nocti.org/teacher**

11. Crittenden, J. B., Requirements for Successful Completion of a Freshman-Level Course in Engineering Design Graphics, *The Engineering Design Graphics Journal*, Winter, 1996, 5-12.

12. Barr, R. E., Planning the EDG Curriculum for the 21st Century: A Proposed Team Effort, *The Engineering Design Graphics Journal*, Spring, 1999, 4-12.

13. Meyers, F. D., First Year Engineering Graphics Curricula in Major Engineering Colleges, *The Engineering Design Graphics Journal*, Spring, 2000, 23-28.

14. Meyers, F. D., Fentiman, A. W., & Demel, J. T., Assessment of the Quality of Preparation of Recent Engineering Graduates in Core Engineering Skills, Presentation - 1998 Annual Conference of the American Society for Engineering Education.

15. URL: **http://www.coun.uvic.ca/learn/program/hndouts/bloom.html**, Bloom's Taxonomy.

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