ADOPTING A SYSTEMS APPROACH TO DESIGN A FRESHMAN COURSE IN TECHNICAL GRAPHICS – MEETING THE SOCIETAL NEED FOR ARTICULATION

Radha Balamuralikrishna, Clifford R. Mirman
Department of Technology, Northern Illinois University

Introduction

The freshman course in engineering or technical graphics has received wide attention in recent times [1]. There is a significant variation in course offerings taken across engineering and technology degree programs nationwide both at two-year and four-year institutions. For example, in problem solving, some courses are solely restricted to structured drafting exercises taken from typical textbooks and others are devoted to an ill-structured design activity or creative problem solving[2]. Similarly, when it comes to computer usage, certain courses involve extensive coverage of CAD commands even at the expense of fundamental concepts in engineering graphics, where as other courses cover very little CAD with emphasis on concepts, pencil sketching and print reading. Coupled with all the possibilities that exist in terms of selecting a CAD package for instruction, it is no exaggeration to say that it has become a nightmare to decide on both the content domain and pedagogical aspects of this introductory course.

This paper will examine the different variations of a freshman technical graphics course and weigh the pros and cons of each. Not withstanding all the differences that exist among engineering graphics educators on this subject in terms of curriculum and instructional philosophy, there are still a large number of course transfers between programs and across institutions[3]. The Illinois Articulation Initiative (IAI) provides a potential national model for seamless transfer of college credit within and between 2-year and 4-year institutions, and technical graphics features prominently on the list of articulated courses. We discuss the prevailing IAI briefly and how it applies to technology degree programs. Our studies indicate a need for further research on best practices for a freshman technical graphics course and ensure that certain basic standards are met wherever the course may be offered.

Technical or Engineering Graphics – An Aerial Survey

A course in technical or engineering graphics is usually a requirement for students majoring in but not limited to engineering, engineering technology, architecture or industrial technology. The importance assigned to this course, if any, does seem to vary depending on the specific sub-disciplines within each of these four broad disciplines. For example, a mechanical engineering curriculum would place greater emphasis on this course as opposed to electrical and electronics engineering. Similarly, a curriculum for manufacturing technology would most likely place a higher priority on engineering graphics than would a safety or industrial distribution curricula. However, it is safe to say that true to the maxim "a picture is worth a thousand words", a required first course in engineering graphics is ubiquitous in engineering and technology education all over the globe. This is a course that enjoys considerable enrollment and arguably, touches the lives of students and faculty affiliated with engineering or technology to a high degree of significance.

During the past two decades, a first course in engineering or technical graphics has also assumed titles such as but not limited to computer-aided design, solid modeling, technical drafting, technical drawing, technical sketching and blueprint reading. To a large extent, these variants reflect individual philosophies and subject matter emphasis much like any other course. Yet, the different variants all have the commonality in that this may be the only 2-3 credit hour course that their students complete in the subject area of technical graphics and related computer skills. Stated another way, this may be the only course that serves the student as she progresses through the degree program completing other courses such as machine design, manufacturing processes, senior design projects, and industrial internships which demand specific skills and knowledge base in technical graphics. Further, if the student intends to specialize in the area of computer-aided design or computer graphics technology, basic technical graphics serves as an indispensable foundation level course.

Designing the optimal freshman course in technical graphics – Nuts n Bolts

The "optimum" represents a balanced view that is struck when confronted with conflicting circumstances, demands, or requirements imposed by the system as a whole. In designing a freshman technical graphics course, we have identified five potential interrelated and interdependent issues that call for compromise and a fair degree of judgment. The compromising stance is essentially imposed by the constraint of "no more than three credit hours" that is typically designated for technical graphics.

Emphasis on technical content

This refers to the subject matter including but not limited to spatial visualization, geometric constructions, theory of orthographic projection, pictorial drawings, section views, auxiliary views, dimensioning, tolerancing, and ANSI/ISO standards. This technical content may be thought of as legacy topics that have been standard in the engineering curriculum for much of the 20th century at least until PC-based CAD systems forced educators to dilute this content in order to facilitate instruction in computer skills.

Teaching/Learning method

At one end of the spectrum, the learning activities could be restricted to highly team based and intensive (semester-long) creative projects and the other extreme would be highly structured standard problems that are individual assignments. A solely team-based approach to learning at the freshman level has the potential to create wider variation in learning among students due to the introduction of factors such as appeal of the selected problem, teamwork dynamics, and attitude towards shared responsibility. From an instructor's standpoint the measurement of individual learning and assigning grades becomes much more complicated. The other extreme of restricting the course to structured problem-solving and promoting isolation among students also has the potential to distance certain learner types.

The medium of practice

Paper and pencil techniques with (drafting) or without (sketching) the use of legacy manual drafting machines continue to fascinate the imagination of a significant number of individuals representing both academia and industry, and there are those who advocate the computer as the sole medium (hands-off pencil) approach. As industries worldwide (more so

in the United States) have discarded their drafting machines in favor of CAD, continued leanings towards manual approaches in education seem highly questionable. Although documented cases could not be found in our survey of the literature, we note from our personal experiences that student cheating is more commonplace in CAD based assignments, perhaps simply because of the ease of reproduction. However, we have also observed that a paper and pencil approach including sketching is looked down as "ancient" by a significant number of students and this "de-motivator" needs to be better understood through documented studies.

Design paradigm
If computer-aided design is included in the course, do you adopt the 2-D detail drawing approach or the 3-D solid modeling approach?
As things stand today, a 2-D detail drawing approach may work better for the technology major and the solid modeling method may be preferred in engineering. Technology majors tend to be more involved with detail design documentation, manufacturing process planning, production, and quality approval functions where 2-D CAD skills would be much more relevant. Engineers focus more on concept design and analysis where the solid model has become the starting point for product design and development using techniques such as rapid prototyping and finite element analysis. However, a 2-D drawing is readily generated from a 3-D solid model and hence is it really necessary for the technology major to study 2-D techniques in isolation from 3-D techniques?

CAD software
If computer-aided design is included in the course, what brand of CAD software would be favored?
This is becoming an increasingly difficult problem to address because of the wide range of possible alternatives, all available at competitive prices. Also, the CAD systems market is highly fragmented in industry. Particularly in mechanical design, we may cite examples including but not limited to SolidWorks, Inventor, I-DEAS, Pro/E Wildfire, Solidedge and AutoCAD all attracting significant numbers of users. The collective input from industrial advisory board members, area industry representatives and other stakeholders including faculty colleagues teaching downstream courses all used with caution should often lead to an appropriate choice of design package. We should also emphasize that because of the depth and capabilities of modern CAD packages, it is impractical to provide instruction using a multitude of software within an academic department.

At this point, we would like to digress from the subject of discussing the details of designing one specific course to a broader perspective of collaboration and articulation of courses within and between 2-year and 4-year colleges. During the past two decades, the increasingly high cost of higher education coupled with the changing demographics of American society forced educators to think of new ways to help students bring their higher education to fruition. One significant form of help to students has arrived in the form of increased number of articulation agreements that enable seamless transfer of courses from one institution to another [4,5,6]. From years of experience advising students, we have observed that the freshman technical graphics course in all its various forms is one of the most frequently transferred course and we would like to examine this course in light of articulation.

Course Transfer and Program Articulation

Within the State of Illinois alone, there are over thirty different 2-year community colleges, and over ten 4-year institutions into which students can transfer courses. While the typical transfer student tends to remain within their geographic region, that area may be served by at least two different four-year institutions. Thus, the transfer of course work is dependent on the agreements in place between the 2-year and the 4-year institutions. In many cases, the course equivalents accepted in transfer vary by school. Thus, it is becoming more important for the transfer students to know where they would be transferring to at the start of their community college career. It should be noted at the start that within the State of Illinois, transfer into to the engineering programs provides the simplest paths toward transfer from the community college [7]. The State of Illinois has developed a statewide articulation initiative, in which there are general curriculum outlines for transfer courses. If a course is submitted for transfer, and meets the curriculum outline, then that course can be transferred from the particular community college to a host of 4-year engineering programs.

This process is not as simple in the technology programs. Even though there is a statewide articulation process for technology programs, since technology encompasses a wide area, most branches of the field are not covered within the process. As such, 4-year and 2-year schools must form their own articulation agreements. This entails the schools and departments communicate to discuss the format and curriculum within the desired courses. In most cases, this entails the community college submitting the specific course syllabi to the 4-year program, and the faculty determines if the offered course is nearly equivalent to courses that they are teaching. The following figure shows one section of the articulation tables for transfer between NIU and Rock Valley College.

ROCK VALLEY COLLEGE

CATALOG YEAR: 2001- 2003 NIU CATALOG: 2003-2004 DATE: JULY, 2003
EFFECTIVE FOR COURSES TAKEN FALL 2003, SPRING 2004, AND SUMMER 2004. PAGE: 4 OF 12

COMMUNITY COLLEGE COURSE NUMBER/TITLE	NIU SUBSTITUTION	IAI CODE
COMPUTER-AIDED MECHANICAL DESIGN TECHNOLOGY (CDT)		
103 MATERIALS OF INDUSTRY	TECH 393	MTM 912
104 MANUFACTURING PROCESSES	TECH EL	MTM 913
141 DESCRIPTIVE GRAPHICS	TECH EL	
142 TECHNICAL GRAPHICS	TECH EL	
150 INTERPRETATION OF INDUS DRAWINGS	TECH EL	
211 INDUSTRIAL ORG AND OPERATION	TECH EL	
220 MECHANISMS (220 + 221)	TECH 214	
221 MACHINE DESIGN (221 + 220)	TECH 214	

Figure 1. Extract from a course articulation table

Examining the issue of student transfer from the 2-year to 4-year institution is a very complex area [8,9,10] and included in this issue is the transfer of the freshman level technical graphics experience. The topic of both programmatic and course to course transfer, or articulation, varies from institution to institution and state to state. In general, the educational missions of the typical Community College and University are diverse. Within the sciences and liberal arts there is a similarity in offerings at the lower divisions, and students are able to matriculate from the 2-year institutions to the 4-year institutions in a relatively simple manner. However, in the areas of

Engineering Technology and Industrial Technology, the two institutions have objectives that are both similar and diverging. Within Technology, there is a group of students that complete 4-year degrees through the transfer process, however, there is also a group of students who enroll in the Community College to obtain specific knowledge which is typically vocational in nature, either in CAD, CNC, and HVAC, to name a few. The mission of the 4-year institution is to provide a broader based technical education, which contains a liberal-arts base and a strong mathematics and science core. Even though each institution has a constituent audience to which it must provide educational programs, there is an overriding need to provide accessibility to students from all of the communities served. The teaching of basic technical graphics is a perfect example of the divergence between the community college and university. At the "typical" community college in Illinois one can find courses which cater to the following groups:

- Engineering student population – CAD class deals with projections, geometric constructions, and dealing with various spatial problems through solid modeling.
- Technology – CAD course deals with some basic theory of technical drawing and application of specific software to produce 2-D drawings and some 3-D part models. Rarely, manual method or a combination of CAD/manual may be used.

Returning to the basic goals of the community college of training individuals to either matriculate to a 4-year school or find employment after graduation, the typical CAD courses in the technology areas have been expanded upon to provide some degree of specialization in the area of design tools. Within the 2-year CAD program at many community colleges within the State of Illinois, students must complete a basic manual drafting course, followed by a basic CAD course. After the basic CAD course, the students typically take advanced CAD, as well as solid modeling, and several additional courses in which the CAD tool is utilized in some form or another. The students who are enrolled in these 2-year programs find either few transfer programs in which all of their credits may transfer, or technology programs in which several, but not all of the CAD-type courses will transfer.

To provide transfer opportunities to the students of Northern Illinois, the Northern Illinois University Department of Technology has developed two distinct educational tracts. Within the Technology realm, the department offers both an Engineering Technology program (Manufacturing and Electrical) and an Industrial Technology program. NIU also offers engineering programs in Electrical, Mechanical, and Industrial. As mentioned before, the varying needs of the community college require that each college offer varying courses to their constituents. If one looks at offerings in the graphics, or CAD, areas, one finds that there are courses offered ranging from the basic levels to advanced, as well as blue print reading, basic and advanced board drafting, CAD design, and solid modeling. The CAD background provided at the community college is very valuable, and the student graduates have excellent skills with which to enter the work force. However, the transfer of course credits into the 4-year institutions with technology programs tend to be more problematic.

At NIU, the programs in Industrial Technology and Engineering Technology are more broad based than the 2-year programs, and thus, lesser graphics course emphasis is used within the programs. At NIU, there is more emphasis placed upon the core areas within math and science, which are used as prerequisites for the various technology courses. Since there is limited space

within the curriculum, needing to adhere to about 124 credit hours for graduation, the number of CAD courses within the NIU Technology programs are typically less than the student would take at the community college. Therefore, it is up to the student and the 2-year school to understand what will and will not transfer. In many cases, the student determines that they would like to continue for a 4-year degree after completing the associate's degree. At most community colleges within the state, this would mean that many credits do not transfer. However, many students follow the transfer process along the route, and they know which courses will transfer between institutions. Through this knowledge, they can take courses that will definitely transfer, thus saving time and money, and obtaining an excellent quality technology education.

This may sound like a difficult process for the transfer students, however, the process has become simplified in the past few years, namely, 2-year and 4-year schools are working together to foster the transfer agreements. For example, Rock Valley College has just initiated Manufacturing Engineering Technology and Electrical Engineering Technology programs which transfer to similar programs at NIU. The main differences in this development are that the faculty from the technology departments at the two schools worked together, and as a result, 64 credits transfer. The two schools are now examining transfer into the Industrial Technology program, which has in the past allowed between 40 and 55 credits to transfer. The ability to transfer coursework is good for all parties involved, students and 2-year and 4-year institutions. It provides the students with a lower cost, typically, quality education for the lower division courses. It also allows the community college to recruit quality students into their programs. The benefit to the 4-year school is an influx of students into the junior and senior years of the programs, one point at which students tend to leave the technology programs.

The present and the future of the freshman technical graphics course in the Illinois Articulation Initiative

The first part of this paper examined the possible variations that exist in the design of the freshman technical graphics course and the second part focused on the practice of articulation[10]. A significant number of technology majors (25-50%) do transfer from engineering programs where they have completed the basic graphics course. Students do expect this course to be transferred into their new program in Technology. Another significant source of students in the 4-year technology program is those students who have completed two years from a community college, and very many of these students would have completed the basic technical graphics course at their point of entry into the 4-year program. It is quite easy to visualize that significant variation in subject matter competency and computer skills relevant to a basic technical graphics course among students in upper level technology courses might exist. This does pose a problem for instructors teaching courses that hinge on prerequisite knowledge and skills in basic technical graphics. The upper level courses could be in an area of technology that is serviced through technical graphics such as manufacturing engineering technology (MET) or it could be in an area that builds special skills in computer-aided design under the auspices of an Industrial Technology or Computer Graphics degree.

We should mention here that variation among learner's background is commonplace in higher education, but what is important here is to recognize that the variation is imposed by the system, which for most practical purposes lies beyond the control of the learner. One relatively simple method to overcome the problem of system induced variation in knowledge and skills among

students completing basic technical graphics is to have a course syllabus with very rigid specifications in terms of subject matter content, depth of content, certain teaching methods, and brand of software used. However, this is not practical because basic issues such as academic freedom do arise. Besides, most variations of basic technical graphics are bound to have parallels at a significant number of other institutions nationwide and it becomes almost impossible to argue for or against one course syllabus, teaching method, or CAD software package. On the other hand, societal needs continue to call for more collaboration and partnerships between institutions. The future direction of a first course in technical graphics promises to provide an interesting challenge for engineering and technology educators, and there should be a renewed sense of urgency in our community to address the issues presented here. In the near future, we plan to complement this paper with a visual model describing the inputs, outputs and impacting elements of this introductory course. The new K-12 focus exerted by ASEE and how fundamental technical graphics can be used as an agent to promote engineering and technology education also promises to emerge as a related area in that model.

BIBLIOGRAPHY

1. Nee, J.G. *Design problems and their infusion into design, engineering design graphics/EDG/CAD curriculums.* In Nee J.G. (Ed.) Proceedings of the NSF Sponsored Workshop on Introductory Engineering Design, Engineering Design Graphics (EDG), and Technical Graphics (TG) Problem Solving, Central Michigan University, Mount Pleasant, Michigan, June 7-15, 1999, pp. 58-66.

2. Dally, J. W. and Zhang, G. M. (1992, February). A freshman engineering design course. *Journal of Engineering Design Education*, pp. 83-91.

3. Yue, J. E. *Teaching freshmen engineering design at a two-year college*. Proceedings of the 2000 ASEE Annual Conference and Exposition, St. Louis, MO, June 18-21, 2000, pp. 5621-5630.

4. Barger, M., Goff, G., and Rogers, H. (2003). *Bridging a Gap: A.S. to B.S. Articulation in Florida*. Proceedings of the 2003 ASEE Annual Conference and Exposition, Nashville, Tennessee, June 22-25, 2003. Paper number 2586.

5. Newman, R., Munukutla, L., and Robertson, J. *Building Bridges with Community Colleges "Partnering for Educational Success".* Proceedings of the 2002 ASEE Annual Conference and Exposition, Montreal, Quebec, June 16-19, 2002. Paper number 3650.

6. Juliano, T.M., Rockland, R.H., Bloom, J.S., and Gonzalez, G. *Enhancing the pre-engineering curriculum - a multi-partner initiative.* Proceedings of the 2003 ASEE Annual Conference and Exposition, Nashville, Tennessee, June 22-25, 2003. Paper number 3547.

7. Mirman, C.R. and Skattum, G. *Community College/University Articulation - A Programmatic Approach in Engineering and Technology*. Proceedings of the 2004 ASEE Annual Conference and Exposition, Salt Lake City,Utah, June, 2004. Paper number 2148.

8. Hines, J.W., Weber, F.E., Prados, J.W., and Gramoll, K. *Transfer Facilitation for Engineering Students Through Distance Education.* Proceedings of the 2003 ASEE Annual Conference and Exposition, Nashville, Tennessee, June 22-25, 2003. Paper number 3486.

9. Hawat, G. and Regis, H. *Articulated Pre-Engineering Programs: How Community Colleges can be Effective Partners with Universities to Deliver Engineering Curriculum to Students.* Proceedings of the 2002 ASEE Annual Conference and Exposition, Montreal, Quebec, June 16-19, 2002. Paper number 3286.

10. State of Illinois Articulation Initiative - *www.itransfer.org/*

BIOGRAPHICAL INFORMATION

RADHA BALAMURALIKRISHNA received his Ph.D. degree from Iowa State University in 1997. Since 1997, he has served as a faculty member in the Technology Department at Northern Illinois University. Radha is an active member of the ASEE and a licensed professional engineer in the State of Illinois. His teaching and research areas are design tools and methodologies, industrial quality, and engineering technology education.

CLIFFORD R. MIRMAN received his Ph.D. degree from the University of Illinois at Chicago in 1991. From 1991 until 1999, he was a faculty member in the Mechanical Engineering Department at Wilkes University. He is currently the Chair of the Department of Technology at NIU. His research areas are CAD, Finite-Element-Analysis, and kinematics, both securing grants and writing publications. Dr. Mirman is actively involved in ASEE and SME.