

Visualizing Construction Curriculum

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The curriculum for a university-level construction management program is dictated by a complex set of constraints and relationships that result in an immense body of data. In its raw form, this data is difficult to use for making decisions and thus it must be filtered to a level that is usable. The resulting subset of data usually takes the form of text-based documents and tables which may or may not be easy to use. This paper demonstrates how information graphics could be used to help students, faculty, industry advisors, and other stakeholders understand the objectives, organization and emphasis of university-level construction program curricula in order to inform decision making.

Key Words: Curriculum; Graphic visualization; Curriculum stakeholders; Communication

Introduction

A typical construction curriculum, like any university program, is defined by many constraints and variables. Constraints of time, program-level outcomes and topical content are imposed by accreditation agencies and university governance. These constraints shape the curriculum, leading to specific courses with their associated course-level outcomes and content. Documentation of the curriculum occurs in many disparate forms including catalog descriptions, courses of study, course syllabi and accreditation reports. Together these make up a large set of text-based data that may be difficult to use or understand by stakeholders in the program. The stakeholders in a construction management program include students, faculty, industry advisors, administrators, accreditors, parents, and even prospective students, each accessing and using curricular information in a different way. For instance, students want to understand how classes are sequenced, while industry advisors are typically more interested in the specific skills that are covered. Administrators often view the curriculum from a resource-usage prospective, while individual instructors need to understand the curriculum's gaps and overlaps.

We propose that organization and presentation of curriculum data using information graphics may facilitate communication among program stakeholders, with the outcome of improving the validity of the decisions that each party makes. This paper provides examples of how information graphics can be used to convey complex curricular information quickly and effectively. The authors make a challenge to the construction education community to conceive of better ways to utilize the large amount of existing curricular information in an effort to improve decision making.

Background

Several approaches have been developed over the last 15 years to collect, map and analyze the curricula associated with secondary and university-level programs. For instance, Jacob's (1997) extensive work illustrates how curriculum maps can be used to analyze and classify all of the variables associated with curriculum design. Learning outcomes templates (LOT) were introduced by Mills, et al.(1996) and Auchey, et al. (1997) at Virginia Tech and further refined by Hauck (1998a, 1998b) at Colorado State University to define and analyze construction management (CM) programs. Their work demonstrates how matrices can be used to organize and analyze curricular information. These templates are useful for faculty and administrators, but their complexity impedes the transfer of useful information to curricular non-experts like students and industry advisors. Communication gaps often occur

when experts who have vast domain-specific knowledge perceive salient patterns that are not obvious to non-experts.
Much of the study in communication theory derives from the seminal work of Shannon and Weaver at the Bell Labs (Shannon, 1948). Communication theory suggests that communication is the conveying of meaningful information from a sender to a receiver, and that communication requires the communicating parties to share an area of cognitive commonality allowing understanding by the receiver. There is also a large body of research that suggests humans use their senses to process information in multiple ways (Coffield, Moseley, Hall, & Ecclestone, 2004; Craik & Lockhart, 1972; Felder & Silverman, 1988). Communication is often enhanced when we exchange information using multiple sensory stimuli. Further, as people access information in different ways, it is increasingly obvious that the growth of information technology is affecting the way we communicate with each other. Today's digital world is highly visual and we increasingly communicate using multiple visual modalities including graphic interfaces. A recent report by the University of San Diego notes that as of 2009 the average American spends 7.83 hours a day with visual media including television, video games, and computer delivered media, and that usage is growing steadily at a rate of over 6 percent each year (Bohn & Short, 2010). Given these developments there is a need to develop new ways of communicating information through graphic media.

Edward Tufte, a leading expert and author of several books (1990, 1997) on the graphical display information, and David McCandless author of *Information is Beautiful* (2009) provide us with strong argument that information graphics allow non-experts to make rapid cognitive decisions about complex information quickly and efficiently. Tufte notes, "Often the most effective way to describe, explore, and summarize a set of numbers-even a very large set-is to look at a picture of those numbers. Furthermore, of all methods for analyzing and communication statistical information, well designed graphics are usually the simplest and at the same time the most powerful." (Tufte 1983, p. 9). According to Tufte "graphics reveal data": To be effective the graphical display should:

- Show the data
- Induce the viewer to think about the substance rather than about the methodology, graphic design, the technology of graphic production or something else...
- Make large data sets coherent, encourage the eye to compare different pieces of data…
- *Reveal data at several levels of detail, from a broad overview to the fine structure….*
- Serve a reasonable clear purpose: description, exploration, tabulation or decoration. (1983, p.13, emphasis added)

The traditional assumption in decision support systems (DSS) literature is that if decision makers are provided with more data they will use this extra data to analyze problems in more depth and, as a result, make better decisions. However, empirical studies investigating the relationship between DSS and decision quality have not borne this out (Todd & Benbasat, 1992). The use of simplified information graphics may help facilitate decision making by providing users with a clearer understanding of complex data. Malcom Gladwell, in his popular-press book Blink (Gladwell, 2005), tells us that rapid cognition is the kind of thinking that happens in a blink of an eye. "When you meet someone for the first time, or walk into a house you are thinking of buying, or read the first few sentences of a book, your mind takes about two seconds to jump to a series of conclusions…. Those instant conclusions that we reach are really powerful and really important" (Gladwell, n.d). This "Blinking" is the cognition that Gladwell uses to describe what experts experience when faced with rapid decision making situations.

The rapid development of information technologies now provides users with a wide variety of easy-to-use and accessible graphic tools including simple graphing tools found in standard business productivity suites such as Microsoft Office, Google Docs and Open Office; software developed specifically for graphics like Adobe Illustrator, Google Sketch-up, Microsoft Visio and Autodesk AutoCAD; and concept mapping applications like Inspiration and SmartDraw. Geographical information systems (GIS) also can be used to produce virtual maps in which the geography represents the landscape of a dataset. By using improved graphics to present data crafted by curriculum experts, useful forms of important information can be provided to non-expert decision makers who lack the expertise to see relevant patterns in the raw data.

Application in Construction Management Curriculum

Since the different stakeholders in a construction management community have different uses for curriculum data, they will benefit from seeing it at different levels of detail and in different organization schemes. Prospective students and their families need to see the big picture so that they can make decisions about selecting a program that meets their needs. Current students need to understand sequences and precedencies so that they can schedule their academic career and understand how the different courses inter-relate. Teaching faculty are focused on individual classes and are interested in the specific outcomes that are expected from their courses, including what they can expect from a student's prior classwork and learning. University administrators are interested in general quality and conformance with rules and standards. Industry advisors want to know how the program will prepare graduates to enter the workplace and contribute to their organizations. Finally, accreditation reviewers need to be able assess the quality of the program against established norms.

Unfortunately, curriculum data can often be difficult to analyze and understand. A compilation of data from the CM curriculum at Northern Arizona University resulted in close to 800 independent course-level outcomes. Of all stakeholders, accreditation reviewers may be best equipped to deal with this raw data because they are well trained in how university programs are designed and assessed. Faculty who work with the curriculum on a daily basis will also be able to use such raw data. This vast amount of information, however, is difficult to use by the other curriculum stakeholders.

Error! Reference source not found. In the following sections, we present sample graphics that we believe address the needs of the various stakeholders. The sources of the data used to generate these graphics include the curriculum of the CM program at Northern Arizona University and the American Council for Construction Education (ACCE) required content topics (American Council for Construction Education, 2010). While this data is intended to represent typical distributions of topical content within a construction education curriculum, the primary intent of this paper is to show the potential usefulness of different graphic representations.

Precedence Schedule: Students and Faculty

Figure 1 is taken from the a CM program of study and is a partial list of courses required to earn a construction management baccalaureate degree. This program of study is provided to students to assist them with planning an academic career and presents a suggested sequence of courses. Once a student deviates from the ideal plan, however, the document reduces to a checklist that is not particularly helpful in determining the critical path or important inter-course relationships.

Freshman Year					
1st term			2nd term		
CM 120	Intro to Building the Human Environment	3	CM 124	Construction Methods II	3
CM 123	Construction Methods I	3	PHY 111 or PHY 161	General Physics I or University Physics I (SCI: LAB)	4
CM 130	Computing in Construction	3	CST 111	Fundamentals of Public Speaking (SPW)	3
ACC 205	Legal Environment of Business	3	ENG 105	Critical Reading and Writing (FNRQ)	4
MAT 125	Pre-Calculus (FNRQ)	4	*LS/DIV*	Liberal Studies(AHI)/Diversity ***	3
xxx 100	Transition to College	1			
	Total units	17		Total units	17

Sophomore Year					
3rd term			4th term		
CM 222	Construction Graphic	3	CM 220	Introduction to Structural Design	3
CM 225	Masonry Systems	3	CM 224	Concrete Systems	3
ECO 284	Microeconomics (SPW)	3	CM 253 or CENE 270	Surveying & Building Layout or Plane Surveying	3
PHY 112 or PHY 262	General Physics II or University Physics II (SCI: SAS)	3-4	ECO 285	Macroeconomics (SPW)	3
ACC 255	Financial Accounting	3	STA 270 or CENE 225	Statistics (SCI: SAS) or Engineering Analysis	3
	Total units	15-16		Total units	15

Figure 1: NAU CM program of study (freshman and sophomore year enlarged)
(source: http://www4.nau.edu/gateway/Global/DPP/2011-2012/CEFNS/Engineering/1112_CMBSX.pdf)

A more useful representation is shown in Figure 2 **Error! Not a valid bookmark self-reference.**(simplified to show just the construction coursework) in which the essential information from the course of study is presented in a time-ordered manner showing precedence and successors for each course. This graphic isolates the construction courses from the rest of the curriculum to show how each one relates to the others and clearly indicates the importance of certain classes (e.g. estimating) to the sequence. As an intermediate step, the entire curriculum could be organized in a flow chart in much the same way as is depicted in Figure 2, however, as complexity increases, the clarity may suffer.

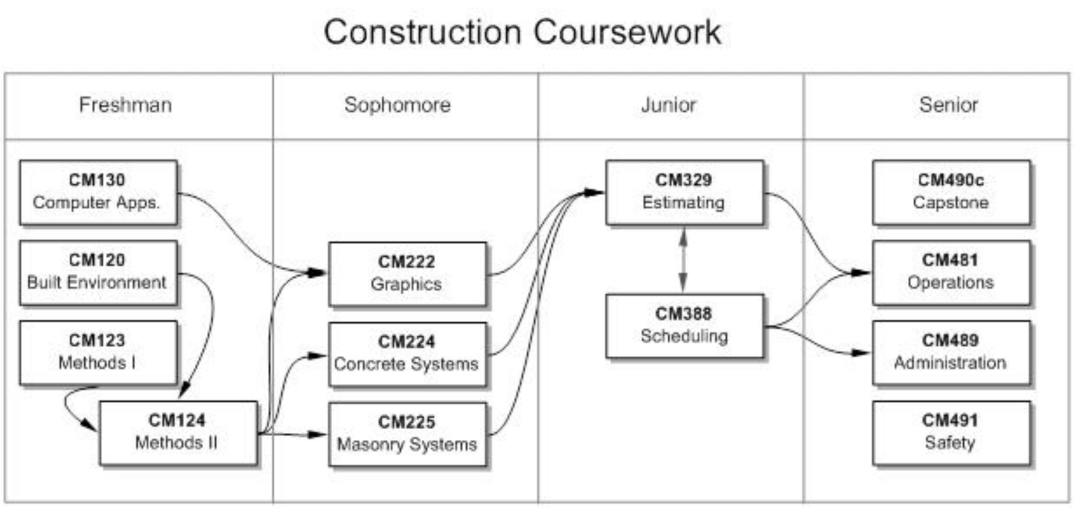

Figure 2: Sequential course of study for construction for classes only

Curricular Emphasis and Float: Industry Advisors

It is the experience of the authors that industry advisors do not fully understand the makeup of the college curriculum or the many constraints placed upon it. Our industry advisors regularly ask us to increase the time spent on a given topic in order to better prepare graduates for some particular demand of the construction industry. We often agree that students will benefit from more practice in a particular area, but find that systematic constraints act to restrict what can be included. The 'chip voting' system described by Olsen and Burt (2010) is a novel way of negotiating this trade-off, allowing the different stakeholders to allocate the limited space in the curriculum to specific topics. To begin such an exercise, however, the stakeholders are required to understand the curriculum and the amount of float space available for negotiation. To visualize this float space, the cube in *Figure 3* could be useful. It represents 100 percent of the curricular hours available for the degree (about 120 semester hours), with the different layers representing the different fixed requirements dictated by accreditation and university guidelines. The top layer, representing the 50 hours available to the construction specific curriculum, has been subdivided into blocks representing the minimum number hours required in each specific topic. The void represents the percentage of the curriculum that is open to the discretion of the program. This graphic illustrates the fixed constraints in a tangible way, showing the curricular 'space' that is open for negotiation.

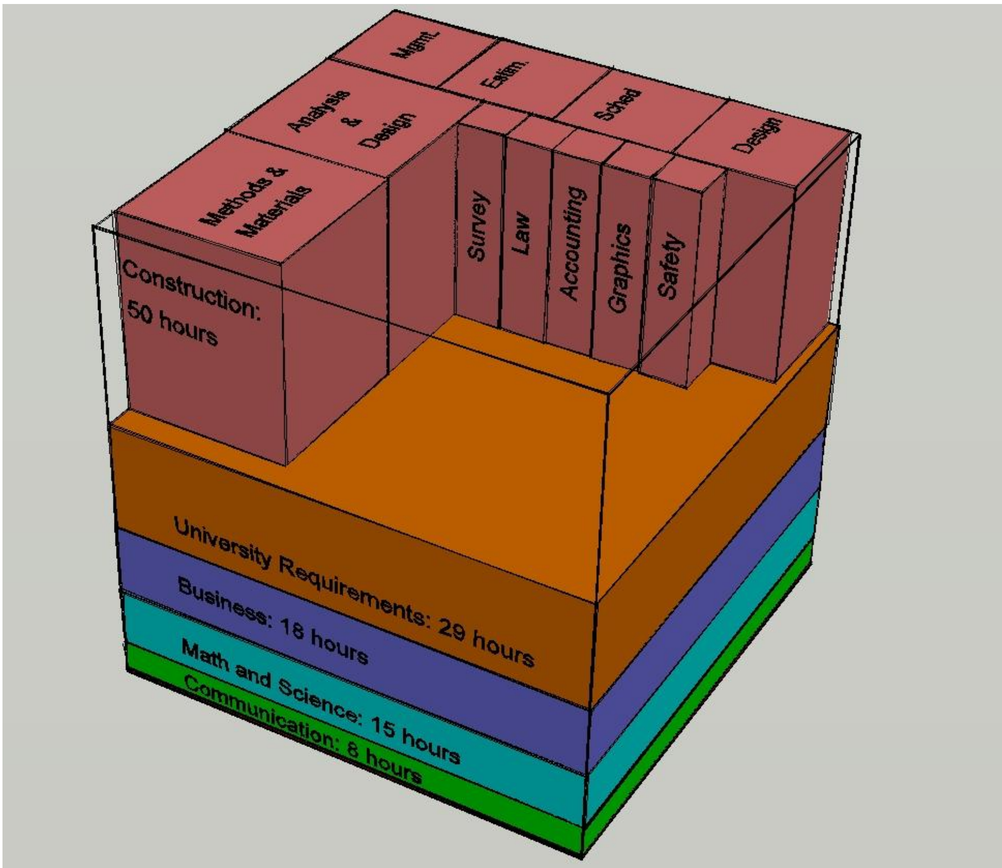

Figure 3: Constraints on curriculum showing float in system

As another example of graphic information, Figure 4 shows an excerpt from a matrix showing the distribution of mastery level for selected skills among different courses. This matrix contains a rich set of data, however this level of detail is not necessarily useful for discussing the distribution of curricular emphasis at the program level. Simplifying this information (*e.g.* professional skills represent 30 percent of the entire curriculum) and presenting the results graphically can help understand the essence of the distribution.

Entry Level Construction Manager Skill Set Level 1: Introduce Level 2: Reinforce Level 3: Master	Ultimate Level	CM 120	CM 123	CM 124	CM130	CM 220	CM 222	CM 224	CM 225	CM 253	CM302W	CM 326	CM 329	CM 331	CM 341	CM 360	CM 388	CM 481	CM 489	CM 490C	CM 491	Business	English + Speech	Math	Science	L.S. Electives	Internship	
Professional Skills																												235
Manages Time Effectively	3		1	1				1		1			2	1					3	3							3	16
Professional Presentations	3		1	1	1	1		2						3				2		3								14
Written Communication	3	1	1	2	1	1		2	2	2	3	2	2	3	2	2				3			1					30
Oral Communication	3	1	1	1		1	1	2	1					2						2			1					13
Graphic Communication	3	1	1	1	1	1	2	2	2	2		2		2	2	2		2										23
Record Keeping - documenting	2			1				1		1		1			1				2									7
Proactive - Takes the next step	2			1						1				2														4
Critical Thinking	2	1	1				1	1	1			1	2	1	1				2	2	2							16
Leadership / Delegation / Teamwork	2	1		1			1	2	2	2		2	3	3	2	2	2			2								25
Negotiates Effectively	2																	1	1									2
Accurate and professional work	3	1	1	1	1	2	2	2	2	2	2	2	2	3	2	2	2	3	2	2	2							38
Global Understanding	1	1		1					2										1							1		6
Ethics	3			1			1				1		1							1								5
Diversity	1		1															1								1		3
Computer literacy - General applications	3	1	1	2	2	1	1	2	2	1	1	2	3	3	2	2		2		3	2							33

Figure 4: Excerpt from skill set matrix: Professional Skills

Figure 5 provides this resulting information in a simple graphic, in which the relative size of the rectangles represent the percentage of the curriculum devoted to different curricular areas (the information in Figure 4 results in the 'professional skills' block in Figure 5). It is important to note that the process of simplifying data will invariably result in a loss of specificity. The preceding example gives a sense of the overall distribution of curriculum at the cost of communicating where exactly within the curriculum each aspect is addressed. It is therefore very important to be clear as to the intended use and audience for any set of data.

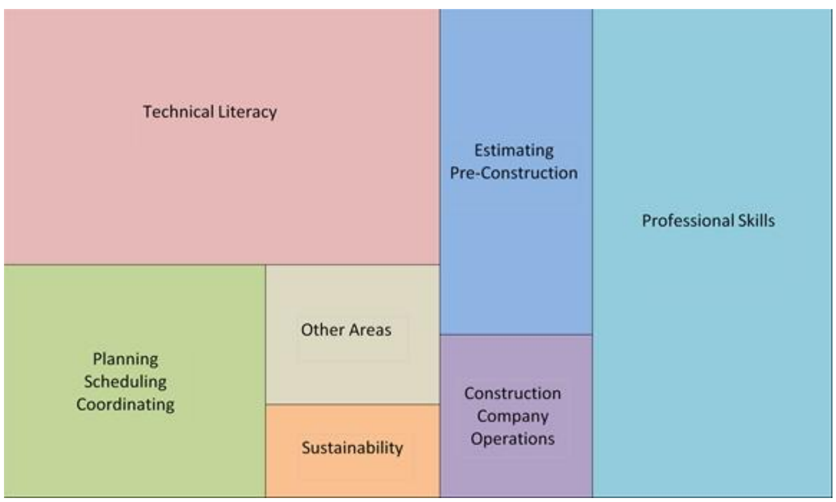

Figure 5: Results of mastery level analysis showing simplified information from Figure 4.

Outcomes and Mastery Level Relationships: Faculty

Each faculty member (or curriulum designer) crafts a specific course to meet many requrements. A detailed analysis, such as applying the LOT to a curriculum, results in a large amount of data. The avaliable data is filtered to provide the curriculum designer a list of outcomes that must be met in a single course, however, the result may still be a large amount of textual information. The tree shown in Figure 6 shows the outcomes that are directly related to the specific area of professional skills for one course, and is an exerpt from a larger tree representing the entire course. This graphic has the immediate benefit of informing curriculum designer not only which outcomes are to be met by the course, but also how they fit into the larger picture of the curriculum. For example the course-level outcome 'particpate in group discussions' is a subset of the program level outcome of 'oral communication'. In this example, the currriulum designer can see that the students have already been formally assessed at the introductory level on this outcome and are expected to meet a 'reinforcement' mastery level in this class. Three subsequent coureses depend on successful mastery of this outcome at the prescribed level.

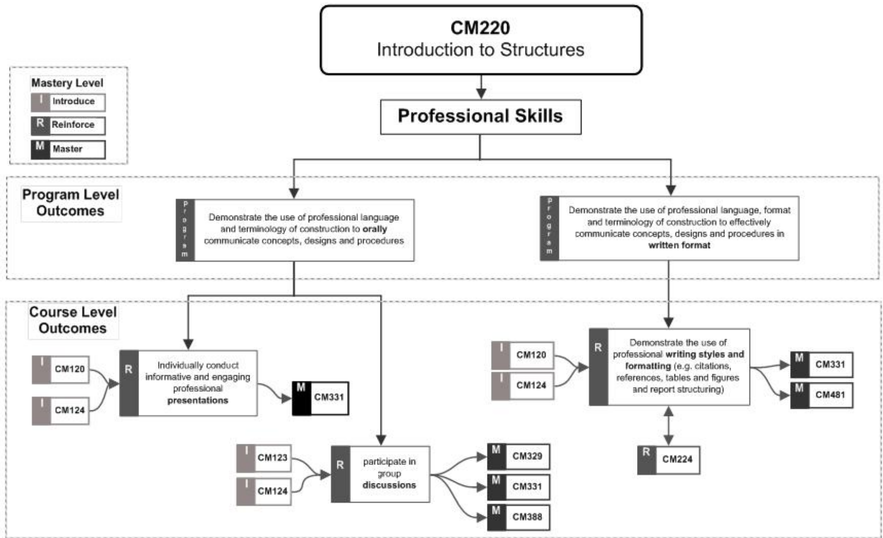

Figure 6: Course-level outcomes showing predecessors and successors and corresponding mastery levels

Limitations

No attempt to organize data is without limitations. The most obvious limitation to the proposed method is the time it takes to organize data and to develop and validate a succinct and meaningful graphic that will best serve particular stakeholders. While examples like Figures 3 and 6 can be very useful, they are time consuming to create, and thus care must be taken when undertaking the process. With a rapidly changing academic and professional environment in the field of construction, it is likely that graphics generated based on the state of a curriculum today will be out of date relatively soon. Automated routines may address these concerns, but they, too will require time and energy to implement. In addition, simplification of data can lead to a loss of precision, so it is imperative to understand the audience and intended use for any resulting graphic.

Conclusions

Decision making is a complex cognitive activity. Experts exert significant effort in developing, organizing and analyzing information. Yet no matter how complex the information is, people typically make more informed decisions quickly when they can "visualize" the information. The rapid development of easy-to-use mapping and graphing programs allows users to create rich information graphics that help diverse users to visualize the curriculum associated with Construction Management programs. The authors have introduced simple examples of graphical presentation of curriculum data that can be used to assist stakeholders in making important curricular decisions.

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