Display cases, catalogues and clock faces: Multimodal social semiotic analysis of information graphics in civil engineering

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Abstract

This paper investigates the social semiotic practices surrounding use of information graphics within the specialized discourse of Civil Engineering. It combines the theoretical considerations of multimodal social semiotics and New Literacy Studies, which offers a conceptualisation of meaning-making as social practice. Methodologically, the paper draws on data collected as part of a two-year ethnographic investigation into the meaning-making practices introduced to students in a civil engineering higher education programme offered by a large, public university in Johannesburg, South Africa. Data was collected through observation and reflection on the part of the researcher, as well as through collection of documentary artefacts.

Three broad social practices surrounding the use of information graphics in Civil Engineering are identified, each of which is characterised by the representational functions they fulfil. The three types of graphics are metaphorically labelled as display case, catalogue and clock face graphics. These are described, and the features of each explained. The paper concludes with brief reflection on how delineation of the social practices associated with information graphics enables understanding of civil engineering knowledge – and the communication and representation thereof – as socially organized.

Keywords: multimodal social semiotics, information graphics, engineering education, social practices, New Literacy Studies.

Resumen

Muestrarios, catálogos y esferas de relojes: Análisis semiótico social multimodal de gráficos informativos en ingeniería civil

Este artículo investiga las prácticas semióticas sociales relacionadas con el uso de gráficos informativos en el discurso específico de la Ingeniería Civil. La combinación de consideraciones teóricas de la semiótica social multimodal y los estudios sobre la nueva alfabetización (*New Literacy Studies*) ofrece una concepción del proceso de creación de significado como una práctica social. Metodológicamente, este artículo se basa en una serie de datos recopilados como parte de una investigación etnográfica desarrollada durante dos años sobre las prácticas de creación de significado presentadas a los estudiantes de un programa universitario de Ingeniería Civil en una importante universidad pública en Johannesburgo (Sudáfrica). La recopilación de los datos se llevó a cabo mediante la observación y reflexión del investigador, así como por medio de la recopilación de artefactos documentales. Se identifican tres principales prácticas sociales relativas al uso de gráficos informativos en ingeniería civil, cada una de las cuales se caracteriza por las funciones representacionales que llevan a cabo. Los tres tipos de gráficos se caracterizan metafóricamente como gráficos de muestrario, de catálogo, o de esfera de reloj. En el presente artículo se explican estos tipos de gráficos y sus características. A modo de conclusión, se ofrece una breve reflexión sobre la manera en que la delineación de las prácticas sociales asociadas con los gráficos informativos permite entender el conocimiento en ingeniería civil –y la comunicación y representación del mismo– como un ente organizado socialmente.

Palabras clave: semiótica social multimodal, gráficos informativos, ingeniería, prácticas sociales, New Literacy Studies.

1. Introduction

Meanings are made using a multitude of semiotic modes, resources and technologies. However, the practice of meaning-making is a "social" practice in that it involves an individual's attitudes towards – and access to – these modes, resources and technologies which, in turn, are governed by social relationships, social rules and social institutions (Barton & Hamilton, 1998; 2000; Barton, Hamilton & Ivanic, 2000; Lillis, 2001; Starfield, 2007). Moreover, as individuals engage in formal learning (such as in higher education), they gain access to different modes, resources and technologies, which alters their meaning-making potential (Barton & Hamilton, 1998; 2000).

This paper works from the three-pronged point of view that a) different meaning-making practices are privileged in different social domains, b) no social practice, mode, resource or technology is valued outside of specific contexts, and c) the meanings and values associated with modes, resources, technologies and practices can vary across contexts (Gee, 2000: 188). Given this, studying towards becoming a civil engineer, for example, involves adopting the meaning-making practices privileged by Civil Engineering as a social institution and enacting these practices during meaning-making events (Barton & Hamilton, 2000; Lillis, 2001). In such meaning-making events, individuals may use language but they do so "in an integrated way as part of a range of semiotic systems; these semiotic systems include mathematical systems, musical notation, maps and other non-text based images" (Barton & Hamilton, 2000: 9).

Using civil engineering study as the specific location for the research, this paper asks what social practices are associated with a particular representational mode, namely the information graphic, a visual display of information used to represent meaning in non-verbal forms. Information graphics commonly take the form of diagrams, photographs, tabulations and sketches, amongst others. They are important in this particular domain because Civil Engineering, as a social institution, relies heavily upon this mode for the communication and representation of meaning, or knowledge. As such, civil engineering students are expected to use this representational mode in order to achieve the social practices associated with the communication of civil engineering knowledge.

The paper is structured such that it begins with more detailed discussion of the theoretical perspective that informs this research, being one that combines the concerns of multimodal social semiotics and New Literacy Studies and applies this theoretical interest to specific disciplinary domains. Thereafter, the methodological basis for the research is described, including the ethnographic nature of the enquiry undertaken as well as the specific procedures used for collecting and analysing the data upon which the remainder of the paper draws. The bulk of the paper seeks to identify and discuss three broad social practices associated with the use of information graphics in civil engineering study. The paper concludes with a brief (for reasons of space) reflection on the implications this may have for the ways in which civil engineering knowledge is accessed and understood.

2. Multimodal meaning-making as social practice

This research combines the theoretical notions of a body of work that has come to be called New Literacy Studies (NLS) with the central tenets of work in Multimodal Social Semiotics. New Literacy Studies begins from the point of view that literacy is impacted upon by the ideologies and sociocultural practices that underpin social institutions. Seminal early examples of this work demonstrate that such social institutions include the family and school (Heath, 1983), as well as the university (Bartholomae, 1985), amongst others. As such, within this view, different "literacies" are drawn on in different social contexts. Higher education, specifically, has come to be seen as a domain in which a particular set of literacies, broadly described as "academic literacies", are privileged at the expense of those literacies practiced in other social institutions such as the family and school. Starfield (2007), Lea (2008) and Lillis and Scott (2007) provide useful summaries of the early work in the area of academic literacies.

New Literacy Studies, specifically, offers the notion of literacy as social practice, which refers to the ways in which individuals use literacy in particular social contexts. Literacy practices are individuals' ways of reading and writing, and NLS takes the position that such practices are informed by individuals' attitudes and feelings as well as social rules, relationships and ideologies (Barton & Hamilton, 1998; 2000). Because these practices are patterned by social institutions, different domains require different practices and, just as some social institutions are more powerful than others, so too are some literacy practices more powerful than others (Barton & Hamilton, 1998, 2000).

However, studies of human communication have come to accept a "de-centring of language as favoured meaning making" (Iedema, 2003: 33), and the concept of literacy as social practice has been taken up in the literature on multimodal social semiotics (Street, Pahl & Rowsell, 2009). In such work, the idea of "literacy" has been replaced by the notion of "meaning-making", to reflect consideration of representational modes other than language. The semiotic domains through which communication and representation take place, while certainly inclusive of linguistic modes, extend well beyond the linguistic domain. Work in New Literacy Studies certainly acknowledges this: Barton and Hamilton (2000: 9) argue that "in literacy events people use written language in an integrated way as part of a range of semiotic systems [including] mathematical systems, musical notation, maps and other non-text based images". But, where NLS falls short is in its theorization of how non-linguistic modes can be integrated with the linguistic and with each other to form multimodal ensembles of meaning. More importantly for the purposes of this paper, NLS fails to account for how non-linguistic modes, such as information graphics, come to signify within particular communities, such as

Civil Engineering, whereas it is exactly these questions that research in the area of multimodal social semiotics seeks to address.

Social semiotics is concerned with "meaning in all its appearances, in all social occasions and in all cultural sites" (Kress, 2010: 2), while the notion of 'multimodality' provides the "means to describe a practice or representation in all its semiotic complexity and richness" (Iedema, 2003: 39). In order to make meaning within and out of the world, we need access to symbolic resources through which we can represent, categorise, configure and comment on our experiences (Ivarsson, Linderoth & Saljo, 2009). Language is one such symbolic resource but it exists alongside myriad others, and increased recognition of this has led to the rise of multimodal approaches to meaning-making which refers to those approaches that understand communication and representation to be about more than language and which attend to the full range of communicational modes people use as well as the relationships between these modes (Jewitt, 2009).

This is important because each mode offers particular potentials for meaning-making and each mode is thus particularly suited to specific representational activities (Kress, 2009, 2010). Kress (2010: 79) argues that "mode is a socially shaped and culturally given semiotic resource for making meaning" and that this may include phenomena and objects that are the products of social work, such as furniture for example (Bjorkvall, 2009), that have meaning due to their social making and regularity of use in social life. That is to say, if objects, such as furniture or information graphics, have particular uses in particular contexts, those objects can be considered to be a mode, as they have a particular social and representational function. It is the particular representational functions of information graphics, as mode, that this paper seeks to shed light on.

But, as in New Literacy Studies, within multimodal social semiotics it is taken as given that different social groups produce representations and meanings differently. That is to say, the signs that different social groups use are made with different means and in different modes. Moreover, these signs are a vehicle by which socially informed individuals realise meanings by using culturally available semiotic resources which are shaped by the practices of social groups (Kress, 2010). Put more simply, social groups, through their socio-historical development and needs, have fashioned a set of semiotic resources that individuals then use to realise their particular intentions and meanings. New Literacy Studies and multimodal social semiotics thus share a common concern with knowledge and meaning as emergent from "social practices or activities in which people, environments, tools, technologies, objects, words, acts and symbols are all linked to (networked with) each other and dynamically interact with and on each other" (Gee, 2000: 184). Indeed, they are both concerned with linking the texts – linguistic or otherwise – that individuals create to their positioning within the social world, and they seek to explain how these 'ways of doing things' come to be taken as implicit and routine, both by individuals and by social institutions (Lillis, 2008). Texts shape meaning-making practices and are themselves shaped by these practices, and the combination of NLS and Multimodal Social Semiotics makes this dynamic the focus (Street, Pahl & Rowsell, 2009). This paper seeks to elucidate the above argument using one particular mode, information graphics, in one particular social institution, Civil Engineering.

3. Multimodal ethnographic research methodology

In addition to being compatible with one another, New Literacies Studies and multimodal social semiotics also lend themselves to investigation through ethnographic methods. Indeed, NLS is strongly grounded in an ethnographic focus on how everyday practices are accessed, understood and interpreted (Street, Pahl & Rowsell, 2009). Similarly, ethnographic work has come to constitute a major strand of the research work in the area of Multimodal Social Semiotics (Jewitt, Bezemer & O'Halloran, 2016). As described in the previous section, this study places the social and the multimodal at the centre of its analytical frame. In doing so, it draws upon some of the key tenets of ethnographic investigation.

In particular, ethnography is concerned with how social groups function and with how participation within social groups is organised (Conteh, Gregory, Kearney & Mor-Sommerfeld, 2005). Moreover, it is concerned with the symbolic forms through which social groups represent themselves – to themselves and to others (Geertz, 2001). To this end, a two-year ethnographic investigation was undertaken into the multimodal social semiotic resources drawn upon during civil engineering study, and the particular meaning-making practices constituted through use of these resources. While the focus of this ethnographic enquiry was broader than information graphics, the present paper focuses solely on the meaning-making practices associated with information graphics.

I spent two years observing participants enrolled in a higher education programme in Civil Engineering at a large, public university in Johannesburg, the economic hub of South Africa and, arguably, of sub-Saharan Africa. During these two years, the student-participants were introduced to the "building blocks" of Civil Engineering, in that they completed courses in Mathematics, Drawing, Communication and Mechanics. These building blocks were then put to use within the context of civil engineering activity in courses such as Transportation Engineering, Hydraulics, Reinforced Concrete Design and Structural Analysis, for example. Upon completion of the programme (including a year of work in practice, which was not observed as part of this study), students would obtain a qualification allowing them to become civil engineering technicians.

Data were collected in two ways. First, information was gathered in the form of researcher reflection. Reflection is an important component of ethnographic fieldwork and constitutes what Blommaert and Jie (2010) call an 'archive of research', which serves to document the research journey undertaken. In the present study, this included "reflective introspection" (Vannini, 2007), in which the researcher reflects on his or her own positioning and learning within the fieldwork, and "interactive interviewing" (Ellis, 1998), wherein the researcher and participants engage in unstructured discussion in which each has equal power to direct the conversation; these discussions were reflected upon afterwards, rather than formally recorded.

Second, data collection involved text compilation. There are particular ways in which social groups represent themselves to themselves and to others. As such, documents, including the means by which they are produced, circulated and used, form an important analytical component for ethnographic work (Atkinson & Coffey, 2011). Such texts are socially produced and construct the objects, concepts and/or people they represent in particular ways; for this reason, Social Semiotics is a useful analytical lens for examining them (Atkinson & Coffey, 2011). The types of texts collected included formal texts produced by the participants for the purpose of assessment, informal texts produced by the participants (such as notes taken during classes or during discussions), and assigned or given texts such as textbooks and class notes.

Analysis of the collected data also took place through two phases. In the first phase, the reflective data were used to identify themes and generate arguments. Reflection is, in some ways, a self-analysing form of data. This is because regular, focused reflection over a long period inevitably involves reflecting on previous reflection, noting where issues regularly arise and grouping issues so as to identify over-arching patterns. As such, although initial reflection was used to "observe indiscriminately in an attempt to get an overall image" (Blommaert & Jie, 2010: 29), these reflections were, through later processing, grouped and broader categories were further reconsidered. This is in accordance with the view that ethnography involves the search for patterns which are gradually discovered and then interrelated with other patterns (Titscher, Meyer, Wodak & Vetter, 2000). Indeed, the strength of reflective data lies not in the accumulation of individual pieces of data, but in the overall observations that emerge over the course of two years of regular reflection. "Progressive focusing" of the data (Parlett & Hamilton, 1972; Stake, 2010) allowed for both breadth and depth in the reflection generated and ultimately led to identification of the social (semiotic) practices associated with use of information graphics in Civil Engineering.

Once the central arguments had emerged from the reflective data, the textual data were analysed with a view to supporting, elucidating and exemplifying these emergent arguments. It was in providing a meta-language with which to describe these texts that multimodal social semiotics came to the fore in this study. This involved a particular application of Multimodal Social Semiotics, in that the focus of the analysis was on social practices – what people do with texts – rather than on the texts themselves, in line with the New Literacy Studies orientation of this investigation (Street, Pahl & Rowsell, 2009). Multimodal Social Semiotics was used to achieve a vertical orientation to the data in that it helped to explore the broad arguments identified in the first analytical phase by examining how they become manifest in the texts students produce. This is in contrast to multimodal approaches that take, as their starting point, analysis of texts. In such approaches, arguments are generated on the basis of established analytical methods such as Systemic Functional Multimodal Discourse analysis (SF-MDA) (O'Halloran, 2004, 2008; Martinec & van Leeuwen, 2009). However, while such methods describe how texts function, they may not facilitate detailed understanding of the processes through which such texts are created, used and re-used. As such, this study does not seek to undertake a systemic analysis of the data collected, in which attempts are made to identify the "invisible underlying patterns" that structure meaning and represent these as "non-linear models" (Martinec & van Leeuwen, 2009: 1).

4. Information graphics in civil engineering study

In this paper, "mode" is defined as a representational system that harnesses particular resources in a routinised way (Kress, 2010). For example, the mode of writing harnesses the resources of font, font size, colour and layout, amongst others. Even a lack of variation regarding these elements, black font only for example, is meaningful and speaks to the interest of the producer of that text. Often these decisions reflect institutional or social norms that are, to greater or lesser degrees, immovable and powerful. Resources, on the other hand, are the building blocks of mode, in that resources allow individuals to achieve specific communicative functions. For example, in writing, use of boldface type allows writers to achieve the communicative function of emphasis. Moreover, a single resource can be deployed across various modes: colour, for example, is utilised (or not) in writing, but also in many other modes, such as film and, at times, information graphics.

The focus of this paper, as has already been established, is on information graphics as a mode regularly deployed within civil engineering study, and how their use appears to occur within a certain set of social practices. Information graphics deploy resources such as axes, colour, verbal elements, pictorial elements, numerical and mathematical symbols, amongst many others. In this paper, the term "information graphic" is used to refer to any form of "visual display" (Gross & Harmon, 2014) to represent meaning in non-verbal forms. This may include photographs, diagrams, tabulations, schematics, cartesian diagrams and the like. Such visual displays of information seem to be particularly important in Civil Engineering. In fact, alongside language, technical drawing and mathematical notation, information graphics are among the primary means that civil engineering students – and practitioners – use to represent meaning. During the two years over which this research was undertaken, the civil engineering student-participants frequently engaged with information graphics, with the number of such engagements easily running into the multiple hundreds, possibly even thousands, when including interactions with them as both producer and viewer.

As will be shown in the discussion that follows, information graphics are implicated in the social practices of civil engineering study, as they are used, taught and developed in order to work towards making meaning in particular ways. To this end, three particular social practices associated with information graphics in Civil Engineering are identified. These practices emerged repeatedly in the reflective data generated, and illustrative examples thereof were found in almost all the modules that the student cohort undertook. In the discussion that follows, these social practices are identified by way of metaphoric references to their meaning-making functions: display cases, catalogues and clock faces.

4.1. "Display case" graphics

The practice of deploying information graphics as "display cases" is standard across a number of fields of study and contexts, and it constitutes a somewhat traditional use of information graphics. In their categorisation of scientific visual display, Gross and Harmon (2014) identify seven categories of information graphic according to the functions they fulfil. These are: presentation and retrieval of data (mainly in the form of tabulations), representation of data trends (mainly in the form of line and bar graphs), representation of arrangements in space (mainly in the form of maps and diagrams), representations of space-time relationships (which occur in many forms), representations that use space as a metaphor (such as flow charts, process diagrams and circuit diagrams), representations as virtual witnesses (in the form of photographs and realistic drawings), and representations of equipment (in the form of photographs or schematic diagrams). This classification is a useful delineation of the social semiotic practices associated with visual display in scientific work. However, as the term 'visual display' implies, most of these practices fall into a broader practice of "displaying" information in either a figure (including photographs, diagrams, schematics and cartesian graphics) or table. While such information graphics present results, or other information, for perusal, they seldom stand alone as meaning-making artefacts; instead, they often form part of meaning-making ensembles. This is akin to the ways in which items in a display case are imbued with significance by virtue of the other items collected alongside them and by the surrounding interpretations provided or suggested by the physical, social and temporal context in which the display case is considered.

To illustrate this point, take Figure 1 as an example. This figure is taken from a report produced by one participant as part of what was required in a module on Applied Mechanics. This report presents the results of the very first laboratory practical that the participants had to undertake in the programme, the aim of which was to prove the principle of the triangle of forces, that is, that forces in equilibrium can be represented by means of a closed triangle. As can be seen in Figure 1, numerous modes are deployed within the larger ensemble: language, scientific (force) diagrams, alpha-numeric notation and, of interest in this discussion, a tabular information graphic. The tabular information graphic fulfils a summary function, whereby it spatially organises and reports upon the results obtained. For Force A, the experimental value provided (4 N[ewtons]) would have been given, the calculated value (6.3N) is determined using Pythagoras' theorem as indicated below the force diagram, and the percentage error (36.5%) is calculated using the experimental and calculated values, as is indicated further below the force diagram. Note that, due to reasons of space, only the calculations for Force A are included herein as the calculations for Force B and C were undertaken in exactly the same way.

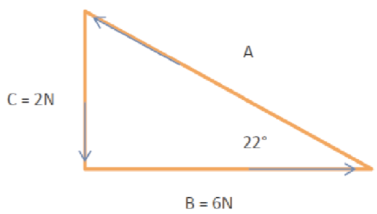
The tabular information graphic provided in Figure 1 shares three particular characteristics with other information graphics that are herein termed "display case graphics". These three characteristics are introduced in the discussion that follows, before two further examples are provided so as to further illustrate these three characteristics and also to demonstrate that Figure 1 is not an isolated instance, but that such social practices are regularly enacted through utilisation of information graphics in routinised ways in civil engineering education and practice.

The results obtained are indicated in the following table:

Force	Experimental Value	Calculated Value	% Error
A	4N	6.3N	36.5%
B	6N	3.5N	- 71.4%
C	2N	1.5N	- 33.3%

These results were obtained as follows.

Assume A is unknown:



From Pythagoras: $A^2 = B^2 + C^2 = 6.3N$

Error = (6.3 – 4) / 6.3 x 100 = 36.5%

Figure 1. Excerpt from report aimed at proving the notion of the triangle of forces.

The first characteristic of display case graphics is that "meaning arises from the accumulation of elements" within the graphic. The individual elements within the tabular representation in Figure 1 draw their significance from their mutual placement alongside each other. The tabular format allows for easy comparison of the experimental values and calculated values for each force, as well as of the percentage error obtained across the three forces. In this way, the tabular representation becomes a "way of arranging a series of semiotic components – verbal or numerical – so that a large number of … propositions can be efficiently generated" (Gross & Harmon, 2014: 55); that is to say, meaning arises from the fact that various elements are accumulated and then spatially organised for easy comparison and contrast.

A second characteristic is that "meaning arises from multimodal ensembles". The tabular representation in Figure 1 does not stand alone as a meaning-making artefact. It is integrated into a multimodal ensemble where, in this case, language is used to co-contextualise the tabular representation. It does this in a number of ways. For example, the tabular graphic is introduced by way of a lead-in sentence ("The results obtained are indicated in the following table"). In addition, the experimental values and methods utilised, such as Pythagoras' equation and the formula used to calculate the percentage error, are discussed earlier in the report. Furthermore, the significance of the results obtained is drawn out in later sections of the report, where the results are referred to and explained. In this case, the experiment was a failure because of the large errors obtained and the report explains this fact, and possible reasons for this error, in the discussion section that follows on from the presentation of the results. This point, that meaning arises from multimodal ensembles where language and image co-contextualise meaning, is not a new one and has been dealt with in the literature on multimodal social semiotics (see Guo, 2004; Unsworth, 2006; Liu & O' Halloran, 2009; Unsworth & Cleirigh, 2009). The point is made here to demonstrate that, in such display case graphics, the information graphic is rendered substantially less meaningful when removed from the surrounding ensemble.

A third characteristic of display case graphics is that engagement on the part of the viewer is limited. The tabular representation in Figure 1 is presented for perusal by the readers of the Applied Mechanics report from which it is taken, but no further engagement with it is envisaged or promoted. The elements within the table are meant to be viewed in the same way as items in a display case are presented for viewing but cannot be touched or engaged with in a physical manner.

These three characteristics are similarly evident in Figures 2 and 3, both of which are taken from unpublished course notes handed out to students during a module on geotechnical engineering. In these two examples, as with Figure 1, meaning arises from the accumulation of elements: shear failure is understood as different from barrelling failure by virtue of their mutual placement alongside one another. Also, the relationship between an underlying strong stratum and overlying cohesive soil is depicted graphically, which draws attention to their interaction in creating a rotational slip failure. But, at the same time, their interaction is also explained verbally, thus forming a multimodal ensemble that is similarly apparent in Figure 2, in which a verbal sentence "introduces" the graphic that follows. Similarly, both Figures 2 and 3 are deployed to display certain information (failure modes in triaxial test samples, or the mechanics of rotational slip failure) but, other than comprehension thereof, little engagement is expected from viewers of these images. These characteristics distinguish these graphics from the other types of graphics discussed in the subsections that follow.

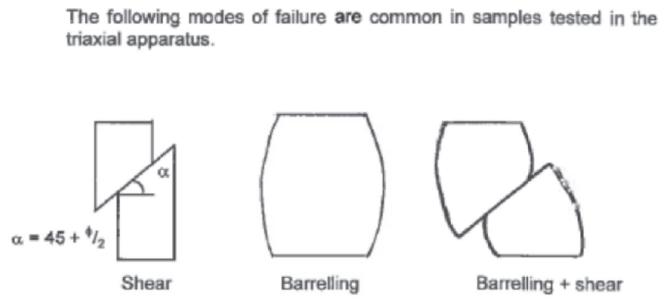


Figure 2. Information graphic from unpublished course notes pertaining to failure modes in triaxial test samples.

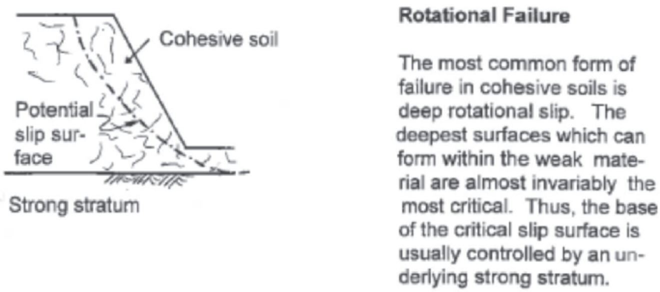


Figure 3. Information graphic from unpublished course notes pertaining to rotational slope failure.

4.2. 'Catalogue' graphics

Contrary to what one might expect, Figure 1 illustrates one of the few instances in which the civil engineering student-participants in this study were required to produce what have here been termed "display case graphics". Although the social practices associated with the use of display case graphics could be considered a standard or conventional application of information graphics as a meaning-making modal system, it was the least common such application in the context of civil engineering study. More commonly, the participants in this study were inculcated into an approach to information graphics that sees those graphics not as tools for the display of information but as integral to accessing the disciplinary knowledge that constitutes Civil Engineering as a field of study.

Much civil engineering knowledge is stored in a variety of information graphics, whether tabular or graphical. These graphics constitute the history of the development of knowledge of the discipline. Examples of such catalogue graphics abound across numerous aspects of civil engineering study and practice. Students – and most practitioners – engage with these graphics, but do not produce them; this is because these graphics represent established civil engineering knowledge – and students use the graphics in order to access this knowledge, but do not build on this knowledge, at least not at undergraduate level. Because these information graphics represent established knowledge, the social practices associated with their use involve identification of relevant properties, rules or factors.

By way of examples, take Figures 4 and 5. These figures are both examples of catalogue graphics, albeit that one takes on graphical form, while the other takes the form of a tabulation. Figure 4, the graphical representation, presents Terzaghi's rules for how pressure is distributed in a braced excavation. In addition to informing viewers how such pressure is distributed in braced excavations, it also informs them that the distribution of pressure depends on the type of soil found. In simple terms, the graphic informs the audience: when excavating in loose sand, for example, calculate the pressure exerted on the side walls of the excavation as depicted in the above image. The tabular representation in Figure 5 presents the influence factors to be used when calculating stress applied on soils by rectangular loads (or forces). This tabular representation not only provides the relevant influence factors but also expresses relationships in the physical world that are core to understanding and undertaking civil engineering activity: stress is influenced by the dimensions of the rectangular load (b[readth] and l[ength]) as well as the depth at which the stress is determined (z). Again, in simple terms, the meaning of this graphic is: given dimensions of length, breadth, and depth, and the identified relationships between them, the influence of the loading on the soil can be described by the specific factor identified.

Unlike in display case graphics, here meaning does not arise from the accumulation of elements; rather, each element takes on different significance at different moments. In Figure 5, more than 300 individual elements make up the tabular representation. However, at any given moment in time, a user of this graphic would have specific interest in only one value, while the remainder of the elements would have little to no significance. For example, given a breadth/length ratio of 0.1 and a depth/length ratio of 0.2, the influence factor, 0.137 (circled in the Figure), becomes the sole significant element in the tabular representation, while the remaining elements are ignored. Similarly, in Figure 4, once the presence of dense sand, for example, has been established, only that part of the figure is applicable and the remainder of the information presented recedes into insignificance. Of course, in another moment, where the presence of soft or firm clay is confirmed, the significance attached to the various elements shifts once more.

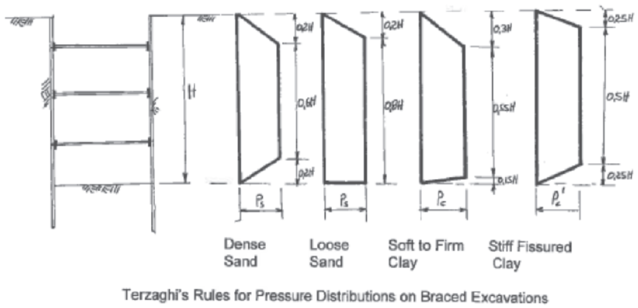


Figure 4. Terzaghi's rules for determining pressure distribution in braced excavations.

Influence factors I for vertical normal stress under the corner of a rectangular loaded area															
b/ℓ z/ℓ	0	0,1	0,2	1/3	0,4	0,5	2/3	1	1,5	2	2,5	3	5	10	∞
0	0,000		0,250	0,250	0,250	0,250	0,250	0,250	0,250	0,250	0,250	0,250	0,250	0,250	0,250
0,2	0,000	0,137	0,204	0,234	0,240	0,244	0,247	0,249	0,249	0,249	0,249	0,249	0,249	0,249	0,249
0,4	0,000	0,076	0,136	0,187	0,202	0,218	0,231	0,240	0,243	0,244	0,244	0,244	0,244	0,244	0,244
0,5	0,000	0,061	0,113	0,164	0,181	0,200	0,218	0,232	0,238	0,239	0,240	0,240	0,240	0,240	0,240
0,6	0,000	0,051	0,096	0,143	0,161	0,182	0,204	0,223	0,231	0,233	0,234	0,234	0,234	0,234	0,234
0,8	0,000	0,037	0,071	0,111	0,127	0,148	0,173	0,200	0,214	0,218	0,219	0,220	0,220	0,220	0,220
1	0,000	0,028	0,055	0,087	0,101	0,120	0,145	0,175	0,194	0,200	0,202	0,203	0,204	0,205	0,205
1,2	0,000	0,022	0,043	0,069	0,081	0,098	0,121	0,152	0,173	0,182	0,185	0,187	0,189	0,189	0,189
1,4	0,000	0,018	0,035	0,056	0,066	0,080	0,101	0,131	0,154	0,164	0,169	0,171	0,174	0,174	0,174
1,5	0,000	0,016	0,031	0,051	0,060	0,073	0,092	0,121	0,145	0,156	0,161	0,164	0,166	0,167	0,167
1,6	0,000	0,014	0,028	0,046	0,055	0,067	0,085	0,112	0,135	0,148	0,154	0,157	0,160	0,160	0,160
1,8	0,000	0,012	0,024	0,039	0,046	0,056	0,072	0,097	0,121	0,133	0,140	0,143	0,147	0,148	0,148
2	0,000	0,010	0,020	0,033	0,039	0,048	0,061	0,084	0,107	0,120	0,127	0,131	0,130	0,137	0,137
2,5	0,000	0,007	0,013	0,022	0,027	0,033	0,043	0,060	0,080	0,093	0,101	0,106	0,113	0,115	0,115
3	0,000	0,005	0,010	0,016	0,019	0,024	0,031	0,045	0,061	0,073	0,081	0,087	0,096	0,099	0,099
4	0,000	0,003	0,006	0,009	0,011	0,014	0,019	0,027	0,038	0,048	0,055	0,060	0,071	0,076	0,076
5	0,000	0,002	0,004	0,006	0,007	0,009	0,012	0,018	0,026	0,033	0,039	0,043	0,055	0,061	0,062
10	0,000	0,000	0,001	0,002	0,002	0,002	0,003	0,005	0,007	0,009	0,011	0,013	0,020	0,028	0,032
15	0,000	0,000	0,000	0,001	0,001	0,001	0,001	0,002	0,003	0,004	0,005	0,006	0,010	0,016	0,021
20	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,001	0,002	0,002	0,003	0,004	0,006	0,010	0,016
50	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001	0,001	0,002	0,006

Figure 5. Influence factors for determining stress in soils under rectangular loads

Such catalogue graphics may present civil engineering knowledge as static but the meanings they give rise to are dynamic, shifting according to the needs and interests of the user; this is akin to the way that certain items in a shopping catalogue meet the specific needs of a consumer depending on their interest at a specific time. Catalogue graphics "house", or represent, large quantities of engineering knowledge in a spatially efficient and easily accessible manner. They are able to do so due to their inherent spatial resources of layout. This has relevance not only for better understanding the resources of such modes of representation, but it also speaks to the nature of civil engineering knowledge where rules, properties and calculation factors take priority over verbal argument, debate and theorization, at least insofar as the discipline is constructed at undergraduate level. This point is revisited later in this paper.

Furthermore, catalogue graphics stand alone, and do not necessarily need to form part of multimodal ensembles, though they can form part of such ensembles as well. Many catalogue graphics include explanatory notes, presented in verbal form, or explanatory diagrams or images. However, where such explanatory representations do exist, the verbal and/or pictorial elements cannot stand alone as meaningful; rather, they rely on the catalogue graphic to become meaningful.

Furthermore, in catalogue graphics, engagement remains limited but is directed in specific ways. As already mentioned, the social practices associated with the use of catalogue-type information graphics involve identifying properties, rules and/or factors. As such, engagement with them is directed at achieving these particular goals. Such engagement remains limited in that the graphics are presented for consultation but are not designed for any other form of engagement. This is significant as they construct the body of civil engineering knowledge as immovable and static. However, consultation of these graphics is not general in nature; instead, it is directed at locating specific properties or particular information. They are engaged with – by students and practitioners – in order to fulfil broader meaningful tasks and thus involve a slightly different form of engagement, albeit still limited, than was evident with regard to display case graphics. Having said this, they do sometimes promote physical engagement: in some instances, a user may run their fingers along the appropriate row and/or column to ensure identification of the correct element in a table with many elements (such as Figure 5). However, such 'bodily' engagement is not a prerequisite for use of such information graphics.

4.3. "Clock face" graphics

Most of the information graphics that the civil engineering student-participants in this study produced are what I term "clock face graphics". In such graphics, a figure or table is underpinned by a calculation mechanism and is used to construct particular knowledge about the physical world. This is metaphorically akin to a clock face that tells viewers the time, but which is the visible outcome of a hidden (from the clock viewer) mechanism that drives the clock face. Often, but not always, these graphics are not subsequently included in texts reporting on the work undertaken by the participants. Rather, the information graphic is utilised and the outcome reported upon, while the mechanism remains unstated and invisible. Unlike the previous types, these information graphics are not used to present information: they are used to construct knowledge. They deploy the spatial resources of graphical and tabular representations in the service of undertaking calculation tasks.

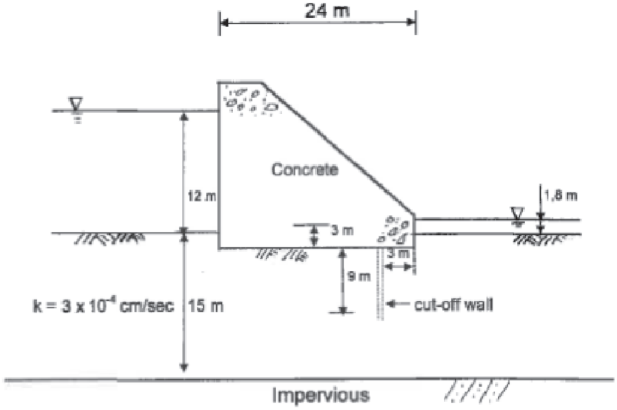
Examples of this type of graphic are necessarily quite complex and, as such, only one example is provided here due to reasons of space. This limits discussion of the practices associated with this type of graphic. However, in this paper, I seek only to draw readers' attention to the existence of this type of graphic and will, in future work, examine the variety of social practices associated with the use thereof. Clock face graphics manifest differently in the case of graphical representations as compared to tabular representations. This is because, in the case of graphical representations, relations in space are used to represent relations in the physical world, whereas in tabular representations, resources of layout are used to assist in calculative tasks. In this paper, discussion will focus on the former, namely, clock face graphics that deploy spatial resources as meaningful in constructing knowledge about the physical world.

When information is depicted graphically, that information is depicted in space and, as such, the elements must be related to one another spatially. This represents the epistemological commitment of graphical representations (Unsworth & Cleirigh, 2009). This spatial relationship reflects a physical relationship between the variables being represented. This, in turn, means that the spatial resources of graphical representations can be used to perform calculation tasks. Examples of this abound in civil engineering study and practice. One such example is that of flow nets. The flow net is a graphical method for determining flow, or seepage, through soil due to differences in pressure. It applies the resource of space to the phenomena of pressure and water flow. It is underpinned by the notion that water will seep through soil from high pressure to low pressure in such a way that there is a linear step-down in pressure along the way. It involves drawing flow lines on a scale drawing; such flow lines represent the likely direction of flow of water through the soil. Thereafter, equipotential lines (lines of equal pressure) are drawn such that they are roughly perpendicular to the flow channels and form squares (not rectangles) with the flow channel lines.

What becomes meaningful for the purpose of calculating seepage flow is the proportion of equipotential to flow lines. Because of this, as long as the flow lines and equipotential lines are perpendicular to one another and form squares, geometrically speaking, the actual number of such lines is irrelevant. This means that two people, drawing a flow net of the same situation, can produce diagrams that look dramatically different but, as long as both have adhered to the geometric rule of forming as-close-to-perfect-as-possible squares, both individuals will arrive at the same answer in terms of the volume of seepage, even if their squares are much larger or smaller relative to each other.

Figures 7 and 8 are flow nets produced in response to the question given in Figure 6, which was given as part of a homework tutorial, hence the correct answer is provided so that students can check their progress and understanding. The flow nets were produced by two different participants. The participants produced them independently of one another in preparation for a test. As such, they were not submitted for formal assessment.

Question 1



Find the seepage in cubic metres per day per metre of dam width without the cut-off wall.

Answer

± 0,83 m^3/day/m

Figure 6. Tutorial question requiring the use of flow nets.

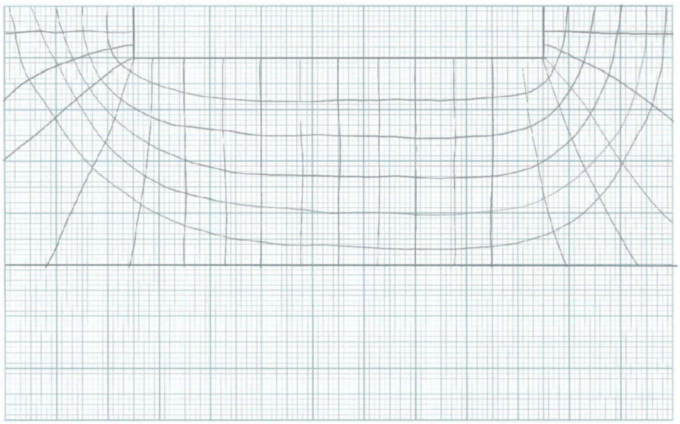


Figure 7. Solution to flow net tutorial question (produced by participant A).

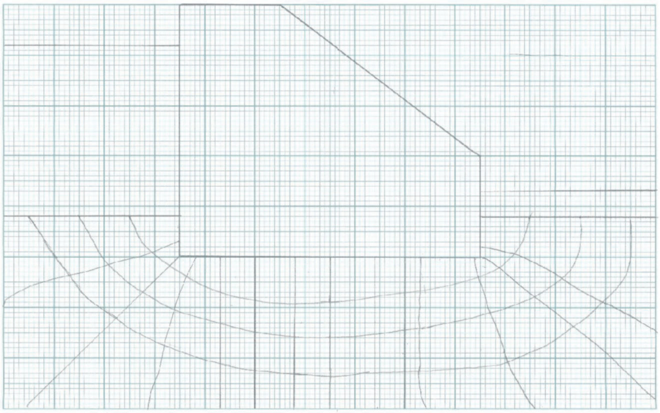


Figure 8. Solution to flow net tutorial question (produced by participant B).

As can be seen in Figures 7 and 8, the two participants represent the given situation differently: participant A presents only the base of the dam structure, whereas participant B presents the entire dam structure. Similarly, while participant A depicts the impervious base of bedrock around midway through the page, participant B uses the bottom of the page to represent this impervious layer. Furthermore, in Figure 7, participant A arbitrarily selected to draw six flow lines and 19 equipotential lines. In Figure 8, the number of flow lines is four and the number of equipotential lines is 13, again arbitrarily chosen by participant B. Despite these various differences in approach, the two participants represent the ratio between the flow lines and equipotential lines, which is what is of interest in answering the given question, as roughly equal to one another. This ratio of flow lines to equipotential lines is inserted into a formula that also includes the difference in pressure that causes the flow, and the coefficient of permeability for the soil under study (this would be calculated using either a field or laboratory test but, in this question, is given). In this case, both flow nets yielded the same, correct answer. What is at stake here is the nature of the use of geometric space, and not the exact number of flow lines produced.

In such graphics, meaning does not arise from the elements presented within the graphic, but from the process of constructing the graphic itself. That is to say, they do not only present information, but they are used to construct meanings that are subsequently deployed in further civil engineering work. Put more simply still, they are used to arrive at knowledge (about the physical world), and not to represent knowledge already obtained. These graphics leverage the particular properties of the physical world that, through relationships that are regular and predictable, lend themselves to being represented in graphical or tabular form. In these instances, the graphic is used to reflect and manipulate these physical properties.

Furthermore, clock face graphics are not, strictly speaking, information graphics. If information graphics are employed in texts with a view to displaying or representing information, then clock face graphics do not, strictly speaking, fulfil such a role. This is because they are utilised in order to determine necessary information which is then taken up in other activities, while the graphic itself is often put aside or discarded, only to be revisited if subsequent thinking requires that the graphic be utilised once more. In the case of the flow net example discussed above, the actual flow net diagram becomes of little consequence once the information it yields has been placed into the relevant equation and the original question (related to seepage flow) has been answered. Clock face graphics thus harness the spatial resources of information graphics in order to visually construct knowledge. They provide civil engineering students and practitioners with the means to regulate and manipulate variables in a spatial manner but do not necessarily fulfil a representational role in the texts they produce. That is to say, such graphics semiotically construct relations between space, time and matter for the purpose of prediction, which other representational forms do not make possible (O'Halloran, 2007). The lines and curves evident in these graphics depict established relations between entities and make these relations visible (O'Halloran, 2007) to civil engineering students and practitioners.

Finally, unlike other types of information graphics, in clock face graphics, physical engagement is a precondition for meaning. While the other types of graphics exist as, or within, texts in order to be viewed, in the case of clock face graphics, physical engagement is an expected part of the meaning-making process. The meanings they give rise to do not exist until they have been physically generated by the student-practitioner through the process of creating the graphic.

5. Conclusions

This paper has argued that different systems of representation, or modes, are put to particular use(s) in particular contexts. In the context of professional domains, such as Civil Engineering, these representational coding schemes are socially organised and represent professional knowledge structures (Goodwin, 1994). The exemplar of information graphics has been used to illustrate this point. It has been shown that three discrete meaning-making practices are associated with the use of information graphics in Civil Engineering. The ability to interpret and produce such graphical information is vital if civil engineering students are to access the knowledge of their chosen field of study. This is due to the fact that significant swathes of engineering knowledge are stored in graphical form and access to the resources by which information graphics make meaning acts as a proxy for access to disciplinary content knowledge. Moreover, these representational practices entrain the cognitive activity of those who use them and constitute the loci of power around which professions are built (Goodwin, 1994). This applies as much to the representational practices associated with other modes – language, mathematical notation, drawing – as it does to information graphics.

Different meaning-making systems, or modes, construct knowledge in different ways. This has implications for the ways in which individuals take up that knowledge. Kress (2010) argues that changes in representation change the potential for representing the world, and that this has important epistemological implications. Information graphics economise meaning in such a way that tremendous swathes of knowledge can be contained within them, which facilitates greater, or at least more efficient, access to this knowledge on the part of students and practitioners. In addition, the visual nature of such graphics recognises and includes those students who may be inclined to absorb such information through visual means. It may, therefore, act to democratise access to information in ways that language does not. It does this also because graphics, and the symbols they employ, transcend language and can therefore be interpreted by speakers of many languages.

However, it is also important to consider the orientations to design, to knowledge and to meaning-making that these uses of information graphics foster. The relatively static nature of some civil engineering knowledge may foster an orientation to design that conceives thereof as the collection of inputs, and the selection of appropriate items from a catalogue. However, this does not necessarily promote an approach to meaning-making and design that places, at its centre, the processes by which knowledge is constructed and that are central to the task of solving hitherto unsolved problems. That is to say, these relatively static practices may serve to obscure the practices by which engineering knowledge comes to be generated, particularly in the case of what have here been termed "catalogue graphics". If "academic literacies in the twenty first century entails being able to navigate multiplicity, [and] to critique representations in multiple modes" (Archer, 2012: 420), the practices described in this paper have important implications for civil engineering pedagogy. These pedagogical implications are beyond the scope of the present paper, but warrant consideration in further work. Moreover, future work should also examine how these practices are (or are not) taken up by engineering practitioners in the workplace domain.

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