Groundwork: Structures and Drawing in Education and the Design Process

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Abstract

At the centre of the design process is the relationship between knowledge and design. This broadly encompasses technology - knowledge - and conceptual thinking - design. The fields of architecture and engineering connect this relationship through separate modes of thinking. In design based education, there arises the opportunity to relate technology into overall design thinking as opposed to the separation into two distinct fields. As education, or pedagogy, is the first prototype for the design process, the integration of knowledge and design can be explored in various ways.

Currently, architects are practised in the use of drawings and models that rarely overlap with engineering analysis, while engineers employ analysis and calculation which commonly remains separate from the holistic design process of architecture. In order to re-link these approaches, the paper explores how the act of 'drawing as thinking' can be re-imagined in the practice of design by architects and engineers in education and the design process. These aspects are researched in the teaching of architecture and engineering students through drawing and sketching which demonstrates how fundamental concepts are developed through matrix-like thinking and are directly linked to the design process. The research concludes that by applying drawing as an active way of thinking, technology can be understood as a system connected to the holistic conception of space in architecture and engineering.

Introduction

Drawing is an activity which relates the intellectual mind and physical body, combined with the faculty of observation and imagination. The paper reveals the characteristics of drawing which have linked the wide field of knowledge and design in an investigation into the practice of 'drawing as thinking' in the notebooks of Leonardo da Vinci [1452-1519].

The paper demonstrates in particular how sketching, as a quick, free-hand use of drawing and modelling, is a basis for the exploration of technological and conceptual thinking related to structural design. This is explored primarily in a collaborative and personal notebook practised by students of architecture and civil engineering under the themes of matrix-like thinking, fieldwork, and the understanding of the 'world as design.' The paper further examines the influence of drawing as a 'common language' between architecture and engineering.

Method

The association of drawing – in particular sketching – with knowledge and design thinking is explored in the core methodology of Leonardo's notebooks. The art historian, Professor Martin Kemp (2001), described Leonardo's use of drawing a way of processing and representing analogous ideas

thorough the ‘interlocked acts of drawing and thinking.’ Kemp used the example of Leonardo’s drawings of swirling water vortices of water, which were generated from his studies of intertwined hair, in order to fundamentally understand its behaviour [see figure 1].

Figure 1. Studies of turbulent flow and water pouring from a culvert, RL 12660v., The Royal Collection, Windsor Castle, Leonardo da Vinci, 1508-1510.

The second key aspect of Leonardo’s notebooks researched is the use of ‘matrix-like’ thinking. In design, matrix-like thinking has been defined by the architect and historian, Tom F. Peters (2003), as ‘empirical, lateral, associative, or intuitive thinking.’ He considered this a ‘multi-dimensional thought form that can use clear, linear thought tracks like scientific method, but it can also jump back and forth from one path to another and even from one level or scale of thinking to another, for instance from practical problem solving to broad historical considerations.’

In this context, Luigi Firpo (1987) wrote that the entire output of Leonard’s *folios* demonstrated a concept of knowledge that was ‘boundless, unique’ and ‘full of infinite links.’ His combined use of drawing and text as part of a personal, creative process allowed him to link a multiplicity of ideas, leaping from one idea to the next in a ‘matrix- like’ way. In doing so, he was able to closely align the creative process to explore knowledge that was open to change and even doubt. This process of sketching and annotation allowed creative ideas to evolve into new forms of knowledge. An example of this was the ‘Studies on solid geometry’ in which Leonardo explored several ways to represent geometric body in lattice-work while speculating on making glass lenses ‘to see the moon large’ [see figure 2].

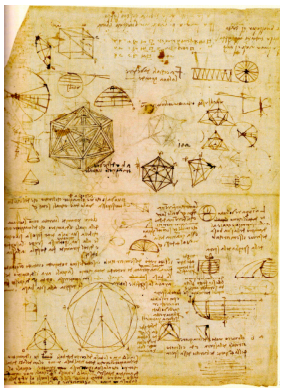

Figure 2. Studies on solid geometry, f. 518 r, Codex Atlanticus, Leonardo da Vinci, c. 1513-14.

The Pedagogical Notebook

These ideas are developed in the use and practice of a notebook for the teaching of structural engineering concepts to architects and engineers in SAUL, School of Architecture and CIVIL@UL, School of Civil Engineering. The 'Gravity + Reaction' notebook is now seen as key component in the development of the incipient stage of education where both architects and engineers are taught in a shared learning environment. This collaborative teaching of structures is demonstrated as a way of linking the fundamentals of knowledge and design in architecture and engineering in their first year. The notebook is adopted under several themes including the act of 'drawing as thinking' in matrix-like thinking, the method of fieldwork, and the understanding of the 'world as design'.

Matrix-like Thinking

The act of 'drawing as thinking' connects matrix-like thinking, further described by Tom F. Peters (2000) as 'technological thought,' to the visualisation and integration of key concepts of structural engineering. As with 'technological thought,' the use free-hand sketching is 'embedded in a multi-dimensional field of choices' and 'can make associative leaps from one linear track to another or from one level of thinking to another.' This is shown in notebook sketches of an 'in-class' experiment by first-year architecture students at SAUL and a bridge design exploration by engineering students at CIVIL@UL respectively [see figures 3 and 4]. In the first example, the experiment shows how a 'bridge' structure, made of a ruler and two straws, would behave using roller joints [see figure 3].

The first sketch shows the movement of the ruler over the roller supports due to the walking action across the bridge. From this, the next sketch shows that there is no movement when the bridge is under a vertical load only. These series of sketches are used to 'jump' from one idea to another as the student develops a network of concepts that relate to the understanding of the type of joint and its behaviour, at different scales. The drawings also make 'associative leaps' from one concept to another. For example, the analogy of two roller blades as a roller joint is shown in a small sketch on the bottom of the page. In the sketch, the roller blades are shown pushing against each other which also means that there is no horizontal movement, as one cancels out the other.

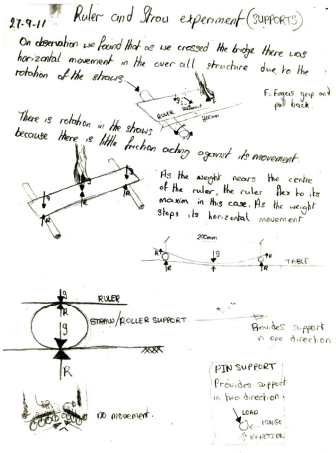

Figure 3. Notebook as matrix-like thinking, ruler and straw experiment, Gravity + Reaction Notebook, Y1, SAUL, 2011-12.

In the second example, the engineer's sketches quickly demonstrate the interconnected parts of the bridge structure design [see figure 4]. Through the use of free-body diagrams, each sketch shows the behaviour of the element including the ties, beams and struts, and moves quickly between scales to demonstrate each part of the whole in a matrix-like way.

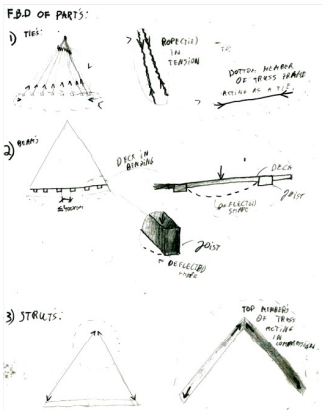

Figure 4. Notebook as matrix-like thinking, Bridge design project, Gravity + Reaction Notebook, Y1, CIVIL@UL, 2011-12.

Field Journal

The notebook is associated with the use of a 'field journal' where observations are recorded directly in the learning environment within and beyond the culture of the design studio. The notebook as a 'field journal' demonstrates that through drawing, knowledge acquired by the designer is not isolated within its own field, but is open to the wider influences and other aspects of knowledge. This approach is shown to influence the means of developing integrated thinking required between architecture and engineering. The practice of drawing also develops the understanding of the underlying behaviour of things as opposed to their representation. This is demonstrated in a field exercise analysing man-made and natural structures. In a series of sketches, the analysis of the structure of a leaf shows how the veins and stem interact with the leaf surface in transferring forces to the ground and its cantilever action is compared to that of a bracket [see figure 5].

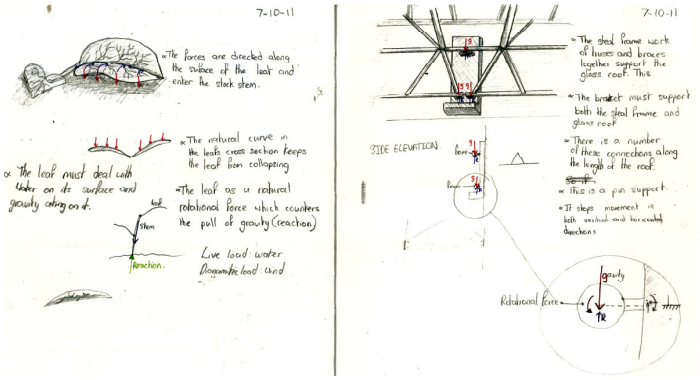

Figure 5. Notebook as 'field work', study of leaf and bracket structure, Gravity + Reaction Notebook, Y1, SAUL, 2011-12.

World as Design

The practice of the notebook relates directly to the exploration of existing and generation of new knowledge. This places the relationship between architecture and structural engineering in context of a larger realm of ideas and design thinking. This is described as 'world as design' which is understood as a broad spectrum of knowledge from that which is observed to that which is created. This is shown in the practice of a notebook where knowledge is discussed on a collaborative basis through design thinking. This is demonstrated in a series of sketches on how floors 'act as a diaphragm' by an architecture student in conversation with an engineer [see figure 6]. A series of bays are drawn as a whole in plan and elevation and analysed as an individual part in a 3D sketch in order to visualise the concept of horizontal load transfer as related to a Design Studio project.

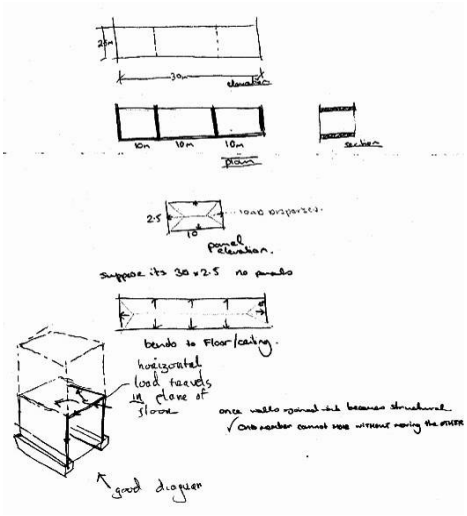

Figure 6. Study of floor acting as diaphragm, Gravity + Reaction Notebook, Y2, SAUL, 2006-7.

Results

The act of 'drawing as thinking' provides a foundation for linking knowledge – technology - with concepts in the design process. Within the framework and methodology of the notebook, and its link to the Design Studio, students can integrate structural engineering concepts into design thinking as part of a continuous development of learning that is neither fixed nor finite. This connects more closely the process of design with the potential for a holistic concept of space. This is demonstrated in a building study which integrates a study on light and the development of a Design Studio project by first year architecture students [see figure 7 and 8].

The building study shows a detailed analysis of load paths, including primary and secondary structure, of the portal frame structure [see figure 7]. Moving from the top of the page, the study leads into an analysis of how the structure interacts with light, as demonstrated in the cross-section in the centre of the page, where it is noted that the north-lights between the bays prevent excessive heat and glare. This demonstrates the successful use of the notebook for matrix-like thinking, in this case by linking structural analysis with other aspects of design in an existing context.

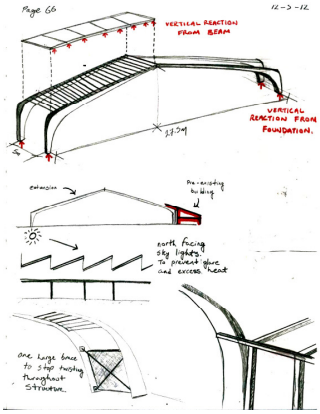

Figure 7. Study of structure and light, Robrecht and Daem offices, Ghent, Belgium, Gravity + Reaction Notebook, SAUL, Y1, 2011-12.

In the design studio project, the drawings describe the synthesis and analysis of a structural bay of an overall design proposal [see figure 8]. The overall sketch on the bottom corner shows the load path for the five spanning elements, four perimeter trusses divided diagonally by a larger truss. Alongside this, there is an analysis of the system which includes an exploration of the internal forces in each of the elements, e.g. compression in the column and bending in the I-beams. Other details show the connection to the column at the top and the base, exploring both materials and stability. These sketches reveal the integrated process of design through the act of drawing as thinking.

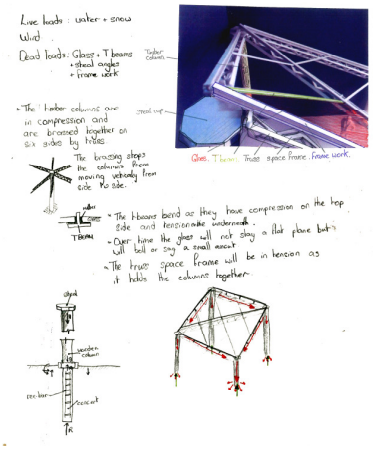

Figure 8. Design studio project, Gravity + Reaction Notebook, SAUL, Y1, 2011-12.

Discussion

The practice of drawing as thinking is essential to the development of a ‘common language’ between architecture and engineering. Through a common language, the synthesis of two fields of knowledge and design can be explored from a more design-based and integrated mode of thinking. This requires close collaboration beginning at the incipient stage of education in order to influence the practice of design. The research provides a basis for this collaboration through the integration of drawing and design between architecture and engineering as ‘matrix-like’ thinking.

References

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