Chapter # 38

SHARPEN CRITICAL THINKING SKILLS TO BOOST FUTURE WORKS

The case of engineers from freehand drawing to digital processes

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ABSTRACT
Learning never stops, and neither does teaching. Re-engaging critical thinking learned at an early age and boosting skills within the university setting play a critical role in shaping a generation of professionals capable of meeting the ever-changing challenges of the modern world. The experience is related to the Building Engineering degree program at the Politecnico di Torino, specifically in the first-year Building Drawing course, pointing out the relevance of the approach from the beginning of the curricular path. The discipline of Drawing, understood as a language of communication for the construction industry, is the element around which an active learning path with students is developed. The scheme adopted provided theoretical notions as the knowledge foundation, then methods and tools between tradition and innovation for representing and analyzing the projects with a critical attitude. Real-world (freehand sketching), digital (Computer-Aided Design vs Building Information Modelling), Augmented and Virtual (avatar in the metaverse) practices are presented to provide a synoptic picture of possibilities that the student may choose to self-consciously employ in further academic courses and their working life.

Keywords: building drawing, critical thinking, mind map, building information modelling, virtual reality, avatar.

1. INTRODUCTION

Nowadays, the modern world is faced with increasingly complex challenges related to globalization, climate change, and the resilience of our cities. On the other hand, the growing technological evolution is enabling broader and more exciting scenarios than ever. These factors are very prominent in the construction sector, which is going through a period of structural change to keep pace with the speed of the Industry 4.0 era.

The emergence related to the digitalization of processes and the introduction of new working collaborative tools, such as Building Information Modelling (BIM), required at the European level by Directive 2014/24/EU (European Parliament, 2014), has demanded from the market not only new skills at a technical level but, above all, a flexible engineering mindset capable of adapting to fast-changing contexts. This element takes on even more significant weight since, according to the World Economic Forum, 65% of children enrolled in primary school today will work in jobs that do not yet exist (World Economic Forum, 2020).

Education will therefore play a decisive role in the following years to bridge the gap between the new industry's demands and the training of young university graduates and ease the transition of workers into more sustainable job opportunities. Consequently, in this historical and cultural context, more than at any other time, there is a pressing need to introduce a revision of degree courses (Osello, Del Giudice, De Luca, & Ugliotti, 2022).

Moreover, distance learning associated with the Covid-19 epidemiological emergency measures experienced in the last few years has introduced new difficulties that have required additional investment to turn the limitations of the virtual environment into current and future opportunities for the students (Ugliotti, De Luca, Fonsati, Del Giudice, & Osello, 2021). Technology-enhanced learning leverages technology to maximize learning within an environment of high-quality course design that can offer students the options of time, place and pace, and emphasizes different learning styles (Huang et al., 2020).

This chapter addresses the particular case of the first-year Building Drawing course of the Building Engineering degree program at the Politecnico di Torino as a leading example of innovative and future-proof teaching practice.

2. BACKGROUND

Digital transformation increasingly requires digital and transversal skills by professionals, companies, public administrations, and citizens to benefit from new services. Hence, the development of critical thinking represents an essential skill in 21st-century learning within educational and professional settings. Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to action. Several interpretations can be found in the literature on the subject (Padmanabha, 2018; Paul & Elder, 2010). According to Dewey, critical thinking is a reflective thinking type that consists of turning a subject over in mind and giving it serious and consecutive consideration (Dewey, 1933). It is a purposeful, self-regulatory judgment that results in understanding, investigation, evaluation, and inference (Facione, Sanchez, Facione, & Gainen, 1995). For Ennis, it is meditative, and sensible thinking focused on deciding what to believe or do (Fisher, 2011). When individuals are capable of using their critical thinking skills to act on opportunities successfully, it can be expected that growth and benefits for the knowledge economy should follow, further developing the capabilities and potential of nation-states (Heard, Scoular, Duckworth, Ramalingam, & Teo, 2020).

Indeed it is the university's job to train students to be increasingly competitive and ready for a world of work subject to constant adaptation. Therefore, the focus moves from the selection and quantity of theoretical content to the learning style for the teaching method aimed at raising knowledge quality (Creemers et al., 2013; Biggs & Tang, 2011) and providing engagement opportunities. According to a recent trend, improving teaching practices requires treating them with the same methodological rigour as scientific disciplines. There is a need for a new synthesis of the instructional development literature (Stes, Min-Leliveld, Gijbels, & Van Petegem, 2009; Hattie, 2009; Samuel & Rahman, 2018). Evidence-Based Education (Pellegrini & Vivanet, 2020) adopts a practice based on the best available evidence. According to Hattie, it is necessary to make the learning-teaching process "visible" (Hattie, 2009, 2012): the objectives must be made explicit, the didactic proposals challenging, the feedback provided and sought, the subjects actively, passionately and enthusiastically involved. Learning is best achieved when the individual actively constructs knowledge and understanding (Santrock, 2001). Individuals must actively participate in the teaching and learning process, thus discovering, reflecting and thinking critically about the knowledge they acquire (Richardson, 2003). Active learning (Brame, 2016) builds on constructivist learning theory (Piaget, 1964), which posits that people learn by connecting new ideas and experiences to what they already know. In light of existing research, teaching structures (Bonaiuti, 2014) are gradually incorporating active learning techniques such as

Participatory Teaching (Concina, 2019), Think Pair Share and Team-Based Learning (Lotti, 2021), Game and Role Playing, Problem-Based Learning, Peer Review, and Mind and Conceptual mapping. Further background and theoretical grounding are provided in the next section concerning the methodological approach used.

3. METHODOLOGY

Now that the necessity to push for innovation in teaching and learning methods has been framed, how to critically and technically explore it? Which role do tools and procedures play in digitalization? This section aims to investigate the strategies that lead to consistent innovation in teaching processes and focuses on the broad theoretical reflection of the current strategies in innovating practices. Promoting innovation in terms of processes and tools in teaching courses is driven by specific and tailor-made strategies that aspire to change the traditional teaching approach profoundly. As mentioned before, preliminary experimentation on the Building Engineering degree program is applied to the Building Design course, which is intended to be the first characterizing teaching of the curriculum. The Building Drawing course tries to embody some of the principles expressed by the cognitivist matrix teaching (Maccario, 2015) and associate the theoretical suggestions with an operative strategy. In fact, the teacher's role (van Dijk, van Tartwijk, van der Schaaf, & Kluijtmans, 2020; Vighnarajah, Luan & Bakar, 2008) both in cognitivism and in the constructivism learning theory is to guide students through the problem-solving process, while allowing them to use their own mental capacities to find solutions. The model adopted seeks to combine teacher-centred teaching, i.e. the didactic approach, and student-centred learning, i.e. the student's active participation. The elaboration of information regarding the connection between topics and matters, individual restitution of results, and critical analysis of process and outcome are fundamental in pushing teaching methods beyond traditional and consolidated procedures. Therefore, the teaching approach of the course takes the following strategic principles into account: (i) supporting the reworking of knowledge, (ii) experimenting with mental strategies, (iii) employing the use of mental resources, (iii) increasing the self-efficiency level of the students.

3.1. Reworking of knowledge

First of all, innovative teaching methods should lean on supporting the reworking of knowledge (De Vecchi, Carmona-Magnaldi, & Della Casa, 1999). The teaching goal is no longer to accumulate knowledge but to structure it, build networks between concepts, and establish a connection between knowledge. What can benefit the development of an articulated network of concepts is addressing a teaching topic by suggesting the employment of several and different technologies to explore from different sides and grade the same object of study. Providing diversified tools and learning strategies can help push students to build critical thinking and cognitive connections. In this context, the Building Drawing course suggests employing several methodologies and techniques in the cross-sectional analysis of a specific object under study, as explained in the following.

3.2. Experiment with mental strategies

Secondly, teachers should encourage students to experiment with mental strategies to push a step beyond mere knowledge transmission. Knowledge is built through a personal work of re-elaborating concepts through which understanding takes place, and knowledge is established. During the Building Drawing course, students are encouraged to elaborate on a personal interpretation of the theoretical topics learned in class and build a concept or mind

map (Tavares, Meira, & Amaral, 2021). Maps are more than a mere graphical representation of concepts and their relationships: they are tools that can help us think better by improving our creative capacity and analytical and reasoning skills. This strategy is aimed at developing meta-cognitive and self-regulatory abilities. Students acquire generative behaviour according to the constructive mode of Michelene Chi's ICAP (Interactive, Constructive, Active or Passive engagement) active learning framework (Chi & Wylie 2014; Chi et al., 2018). In this way, they can generate additional information, which may contain parts of new knowledge compared to the material provided by the lecturer and go beyond what has been presented.

3.3. Employing the use of mental resources

The teacher not only provides the strategies but also helps students employ the use of mental resources (Mazzoni, 2001). It is fundamental that an individual is guided to understand that resources must be dedicated during a study activity and, secondly, how many resources must be dedicated and for how long. It is strategic for a student to ask himself how much (cognitive) effort must be used to tackle a task. How to reach this objective? The teaching course's clear organization concerning topics, objectives, technologies employed, and expected outcomes helps provide a precise reference context. The task of a teacher is not only to organize the resources but also to help students by employing them at different levels at different times. The Building Drawing course is organized to put different organizational, cognitive and technical resources into action to accompany the subject in its growth as an autonomous individual and student. According to the Experiential Learning (Kolb, 1984) process, the "learn by doing" is used to engage students.

3.4. Increasing the self-efficacy level of the students

The weaving of the strategies described must lead to the last point of discussion to consider the needed increase in the self-efficacy level of the students. This aspect represents a crucial and fundamental element because it focuses on nourishing the students' cognitive resources in evaluating themselves. It aspires to help students not so much to understand if they have done well or poorly but because they have achieved a specific result. It can positively affect self-efficacy as it helps to evaluate their performance to recognize functional processes and those that are harmful to increase the possibility of self-regulation and the confidence to better face future difficulties. Concerning this, the pedagogical strategy of Team-Based Learning (Parmelee, Michaelsen, Cook, & Hudes, 2012) provides support with problem-solving, group work, and peer review activities. Students evaluate each other on each other's contribution and intra-group dynamics, reinforcing the importance of both individual preparation and team participation. The Building Drawing course promotes a calendar organized in weekly steps of validations supported by the teacher and tutors at different levels and with different and complementary competencies to help students develop practical activities. Students are accompanied in developing their exercises by weekly reporting difficulties and achievements. They are put into proof to have defined a critical and personal reflection on the practical work.

4. COURSE APPLICATIONS

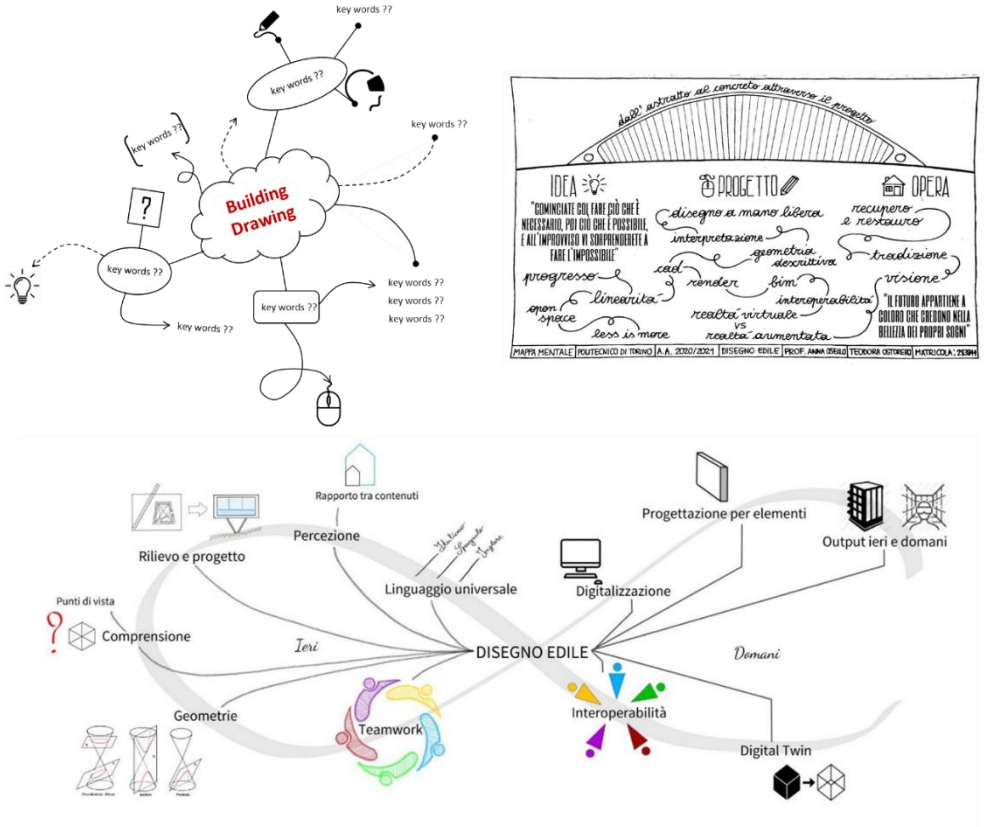
The Building Drawing course aims to set up the methodological elements of drawing as a communication language for the building engineer, providing tools and methods between tradition and innovation for representing both survey and project. The theoretical concepts concerning descriptive geometry are declined in practical exercises, freehand sketches, and technical drawing, including innovative visualization practices. Going into the details of the experience, an attempt was made to implement the strategic principles previously outlined in the teaching by providing an articulated plan of action. As the literature reflects, "Learning involves a combination of discussion, practice and production, working together to practice new skills and creating collaborative work by challenging each other and reaching agreement" (Laurillard, 2012).

In particular, an effort was made to design participatory teaching and interactive learning techniques concerning the theoretical modules. Active reflecting activities on specific topics are offered, asking students to ponder what they already know about a subject. As an example, the launch of the course is handled through a brainstorming activity on the meaning of Drawing, what it expresses and what it helps us communicate in engineering and architecture. At the end of the lectures, on the other hand, the teacher promotes an exercise in summarizing the concepts, highlighting the connection of the new information concerning their real life and how they will apply it to the world through a concrete application. This task also allows a continuous check of the skill gap or mismatch against market needs. Interaction with students is managed through audience response system (Wood & Shirazi, 2020) tools such as Padlet, Kahoot, and Google docs/forms.

To further mark each lesson, students are targeted for a conceptualization activity by self-reflecting on arguments addressed in the course. In this framework, an operative strategy adopted is the development of a mind map to pick representative keywords collected from lesson to lesson, put them in order, and trace connections among the topics, reworking the relationships by using a graphical means. This personal global overview and interpretation of the topics of the teaching formulated by the student are used as the basis for the initial discussion of the oral final examination. Two examples from the Building Drawing course, a.a. 2020/2021, are shown in Figure 1.

The practical exercise involves individual work in the initial weeks of the course, which becomes group work in the predominant part of the course. This choice aims to foster the development of soft skills in university teaching from the early years through experimentation with teamworking, networking, and no less conflict resolution. These skills then become relevant in consideration to the future professional activity of the building engineer, who will always have to collaborate with various other stakeholders for any project's success. As the students are in their first year, they are asked to reproduce an author's project to begin to familiarise themselves with the theoretical content and govern the tools. The case study selected should be explored comprehensively by students through a gradual learning path of representation techniques. It involves the employment of freehand sketches, bi-dimensional and three-dimensional digital drawing, parametric design, and Augmented and Virtual Reality. The aim, therefore, is not to make a vertical focus but to investigate the potential and limitations of different instruments. While freehand drawing is well established in scientific social research as a tool for critical reflection, the adoption of advanced digital tools is still underestimated in terms of methodological approach.

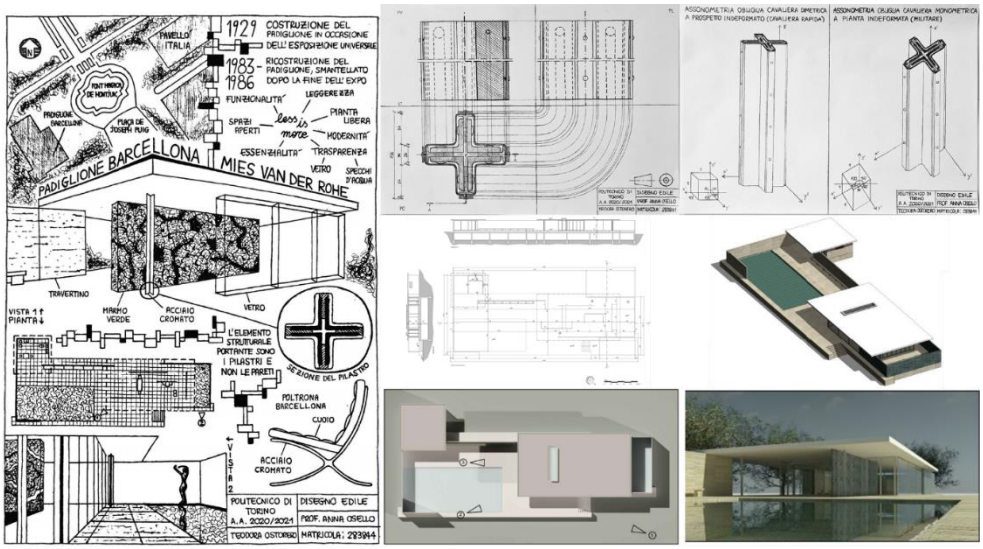
Figure 1.
Mental maps outcomes.



The tools represent a means better to control not only the design but especially the processes. In this sense, it is essential to transfer the method to the students to interface with the instruments rather than merely sharing commands referring to a specific software popular at the time. Using different but complementary operative solutions helps students analyze the object in different scales, perspectives, and technical means. The outcome is deeper learning of the whole object's characteristics, relationships between the parts, and connection with the surrounding. The students are asked to begin the process of investigating the building, starting with the creation of sketches. The anthological drawing is a personal, reasoned, critical reading where the most significant information about the artefact must be selected, drawn, and written down. The theoretical contents relating to orthogonal and axonometric projections are declined in the following practical exercises, always requested freehand, having as object a specific characterizing element of the author's project. Training on digital representation is indispensable nowadays. However, it is the job of university lecturers to select and transfer the most advanced methodologies that find application feedback in the professional and procurement world in addition to the more traditional and established practices. Over the past two decades, in fact, Building Information Modelling (Osello, 2012) understood as the process at the heart of the construction industry for exchanging information during the building life cycle has taken hold. Within this method, BIM tools enable the creation of parametric digital models beyond simple three-dimensional representation by

setting up a database of information. This software category allows graphic and alphanumeric data to be transmitted to other applications and professionals through technological, procedural, and organizational interoperability concepts. Students must return drawings of the author's projects either through Autodesk AutoCAD, a Computer-Aided Design software universally used for drawing and design, or through Autodesk Revit, a model authoring software specific to the construction sector. This work aims to accustom them to the different demands that may come from the market. The approach and working procedure are entirely different, even though the final output of the design boards must provide the same depth. This activity, conducted on a small project so that it can be governed as best as possible, is intended to have students critically compare the different possibilities the software offers. The Engineer must govern the tools, optimizing the solutions according to the representation objectives. Figure 2 shows the example of the Mies van der Rohe Barcelona Pavilion case study from the Building Drawing course a.a. 2020/2021.

Figure 2.
Gradual learning path of representation techniques.



In the last part of the course, theoretical lectures also glance toward using new Augmented and Virtual Reality technologies to present projects effectively. This aspect is also considered very important to complete the framework of the Building Drawing in the third millennium. Accordingly, applications are encouraged to experiment with this returning. The employment of Augmented Reality is required to provide additional layers of information during the presentation of the drawings at the examination. These may include images, videos, virtual tours made from the realized models, and websites.

Moreover, students experience immersive Virtual Reality for their project reviews using Iris ProspectVR software and HTC Vive and Oculus Rift hardware. As can be seen from Figure 3, the teacher becomes an avatar who can interact with students in cyberspace to verify the project, the correct construction of elements, and their assembly, dimensions, proportions, and construction nodes. User perception is amplified, and discussion becomes interactive among the participants because it is possible to take note of critical points by employing instruments for taking screenshots, writing comments, and highlighting errors

inside the model (Ugliotti, De Luca, Fonsati, Del Giudice, Osello, 2021). Being able to navigate the three-dimensional digital models from the inside at the same time certainly contributed in terms of collaboration and involvement of the students. This experience stems from the needs related to the recent pandemic, which has promoted further opportunities to innovate teaching by adopting tools that stimulate creativity. Given the initiative's effectiveness, it was considered to be a regular activity during the course. The purpose is primarily to evaluate their work from another point of view. In the second instance, students must acquire the elements to evaluate possible further application contexts in the professional field. Today is an interaction with the teacher; tomorrow could be the way to interact with other professional firms, the presentation of a project to a client, or the involvement of stakeholders within a service conference.

Figure 3.
Immersive Virtual Reality experience for project reviews.

5. RESULTS AND CONCLUSION

Learning takes place through the organization of knowledge by the subject. A person learns when s/he can connect the information from outside to her/his own knowledge to build organized structures. The organization of knowledge leads to the construction of concepts or logical categories that are more and more comprehensive, articulated, and related through logical links. Therefore, the student must be helped to manage their own learning in an increasingly autonomous way, developing a strategic attitude. The chapter aims to illustrate how these theoretical reflections can become practical strategies to make teaching principles feasible. The Building Drawing course at Politecnico di Torino is the fieldwork where these teaching and learning objectives are put into action and are experimented into a practical context. The enrichment of the course offering is student-centered who can, on the one hand, benefit from advanced didactic experimentation proposing collaborative tools establishing interactive virtual learning environments and, on the other hand, can develop a strategic attitude and working method to approaching complex problems. The results obtained represent an initial proposal to evaluate the potential of the adopted technologies to support teaching and their impact on students' learning processes based on critical thinking. Through

the introduction of diversified active learning strategies in the course, it has been noticed an increasing involvement of students compared to previous years, both individually and in groups. At the end of the course, students have acquired the competence to critically interpret building form and geometry and the ability to choose the most appropriate representation to achieve a given goal. Student enrichment has been noted through student-teacher interaction improvement, the achievement of final products' quality related to the specific course, sometimes higher than required, and the application of these skills in subsequent student work.

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KEY TERMS & DEFINITIONS

Avatar: graphical representation of a user within a virtual community who can move freely and interact with the virtual environment in which it is immersed.

Building Drawing: means representing thought and expressing a project (architectural or urban planning) by which a design hypothesis is shaped and through which the congruence between formal image and construction technologies and systems is verified.

Building Information Modelling: methodological process for specifying, creating, and managing digital information about a built asset.

Critical thinking: ability to analyze information, situations and experiences independently and objectively, distinguishing reality from personal impressions.

Mind map: a form of graphic representation of a thought or a subject devoted to creativity, memorization, and annotation in a personal key.

Virtual Reality: three-dimensional computer-built simulated Reality within which the user can immersively navigate, move and interact with the recreated digital world through special visors.

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