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## How digital tools are changing architecture education

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### Abstract

The article presented here takes a step back from 25 years of teaching in schools of architecture to analyze the challenges and issues related to digital tools. Two schools are compared, the Ecole Nationale Supérieure d'Architecture in Nantes, France and the FAMU in Tallahassee, USA. The precise analysis of the courses and the inventory of the tools used shows distinctly two modes of operation from which we forge two concepts: one, which we call “ legacy “ makes no particular distinction between an analog or digital practice and tends to privilege analog tools. The other, which we call “emergence” is based on the almost exclusive use of digital tools by proposing a cybernetic thinking

**Keywords:** Pedagogy, education, digital design, digital tools, parametric design

### 1. Introduction

This article takes a step back to observe the context in which architectural education takes place. We will do so at our two schools, one in France and the other in the United States. We are two professors with more than 20 years of teaching experience in schools of architecture and both of us started teaching at the beginning of the year 2000 when digital tools, then classified as “ informatics “, were slowly starting to appear in schools. Prior to that, we had been the pioneering students who were monopolizing the few computers in their schools and were called upon early on to teach software in a relatively hostile environment.

The role of digital tools is a question that we continue to enjoy avoiding in pedagogical debates. The phrase “it’s just a tool” de facto disqualifies deeper questions that we should, as professors, explore before even confronting ourselves to students. As those tools are pervasive, their legitimacy does not appear to be a topic of discussion anymore. At the same time, mastering them at a higher level excludes by default non-experts from relevant evaluations. It is thus necessary to change the angle of analysis. In order for the debate to evolve, we should no longer paradoxically take digital tools as the entry point for reflections that we can transfer to pedagogy, but take them instead as one of the indicators, or one of markers of the pedagogy proposed to students. In the process spanning from the question and the delivery of objectives to the production carried out by students, digital elements emerge as indicators of the complexity that we can find again, for example, in the calculation of structures, environmental responses, the generation of forms or the inclusion of a set of politically or socially contextual data.

Today, our duties are to build the education of tomorrow. We have to be at the forefront of the tools evolution but not in the fascination of tools or techniques that we have seen coming and going and then coming back in a different form. We will distance ourselves from the usual debates concerning the role of tools in creativity in order to make a conceptual proposal that can help the analysis which are the notion of legacy and the notion of emergence. Why this? As pedagogues and teachers we are in charge of the future of education in school of architecture, we must constantly question whether or not there are paradigm shifts. Are we doing better with digital tools, are we thinking better or differently? It is the search for this paradigm shift that we are looking for as an invisible frontier between legacy and emergence. On the legacy side, digital tools only reproduce in a different way what was already done; on the emergence side, we are entering the world of innovation.

Methodologically speaking, we have observed our programs and the unspoken parts of our programs. What they deal with, how they do it, what questions do they raise and finally what tools do they mobilize to develop an architecture project. After long iterations, we came up with this formatting that distinguishes quite clearly between what is inherited and what is emerging, in other words, what corresponds to deeply rooted ways of thinking in teaching and practice and what is the result of paradigm shifts. This is independent of the practice of the tools, since Grasshopper can reflect an approach that is as much part of legacy as it is part of emergence.

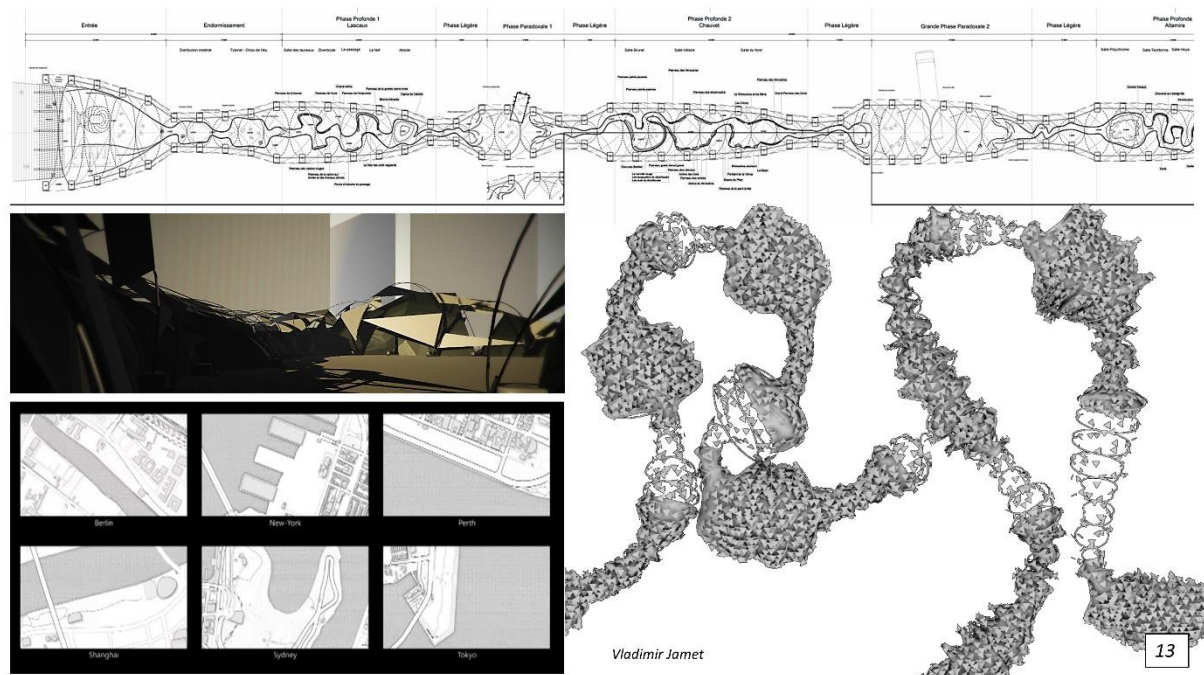


Fig.1 Vladimir Jamet, Master 2, ensa Nantes, parametric generation of architectural plans.

Identifying our modalities - legacy/emergence -, then finding where they stand in the teachings of the project, allowed us to highlight one last fundamental point. The most recent digital tools require us to evaluate not only the result that has been obtained but also, and above all, the process that led to this result. We cannot stress enough the importance of this. Indeed, 20 years ago, whether a plan was executed by hand or on Autocad hardly changed the way we were going to apprehend the project. Today, the implementation of a BIM format, a Grasshopper definition, the simulation of a solar, thermal or aeraulic phenomenon, procedural modelling and even the creation of a rendering image requires us to understand and grasp the process, simply to verify whether the results are valid or not. The teacher must know the process in order to be able to accurately evaluate the result. In our schools, there is a lack of competences for process evaluation.

## 2. Research question: legacy and emergence

We already mentioned it in the introduction, but it is important not to mistake the technical evolutions supported by instrumental improvements and the renewal of paradigms regarding the representation and the communication of knowledge. If the new technologies have exhausted the old paradigms, we should already be particularly careful with the ones that are emerging before us. On the contrary, if we are in the middle of a sort of reformulation, our role is thus to outline the continuities from old concerns to current tensions. That's where the concepts of legacy and emergence that we forged could help.

### 2.1 The modality of legacy

The modality of legacy represents the dissemination of a content and falls within a continuum. The concept of legacy, understood here as professional, scientific and technical legacy, is conceived as a series of interdependent periods that each aims to exhaust a theoretical or technical paradigm. In architecture, there are two modalities of legacy. The first one is that of the profession that, through practice and through education, guarantees the transmission of a content and a protocol integrating the origin of the content and the way how upcoming contents are built and organised. Interestingly, through the will to identify proper architectural research, it was integrated in the second modality of legacy: academic research, which defines and organises the production of professors-researchers. We connect some disciplinary and scientific values to this transmission, and they justify the fact that we distance it from certain elements that do not ensure the maintenance of the prior meaning. This transmission is mainly part of the continuation and the defence of a legitimacy that is acquired only by the mastery of codes and recognition from the peers. Therefore, authorities are necessary, not only to perpetuate this modality, but also to make it work like teleology, i.e. with a goal that is obviously the preservation and transmission of a status. The Order of Architects, the academic institutions, the education and the validation of knowledge all fall within this narrative, with a clear desire to reach universality. A form of transcendence can be found in this approach, with the creation of symbols and rituals recognised by the public to create social adhesion to the professional and scientific authority.

### 2.2 The modality of emergence

In contrast with the modality of legacy, we have a movement that could be called the modality of emergence. The modality of emergence does not work according to the principle of succession like legacy does; it is not linear. It is, in fact, a modality that needs to be carried out, i.e. activated. Once activated, it can – and it should – demonstrate the permanence of what is considered as such. The authority that activates this modality acknowledges its origin, thus validating its authenticity. In France, it could be the network of research laboratories and institutions that measure the value of productions. The modality of emergence aims to link fidelity to the origin, here to the production of the project as well as academic canons, which leads to the search for a holistic experience, i.e. complete. By defining architectural research as a committed reality, a dialectic

relation between research in architecture and society appears, in which the research is carried out. This dialogue must be maintained to face contemporary questions, identify the birth of new practices, and, perhaps paradoxically, seek a holistic plenitude and uphold the value of the architects in their own practice. It is therefore within a modality of emergence that we must observe the influence and application of ideas and tools offered by the digital world surrounding us.

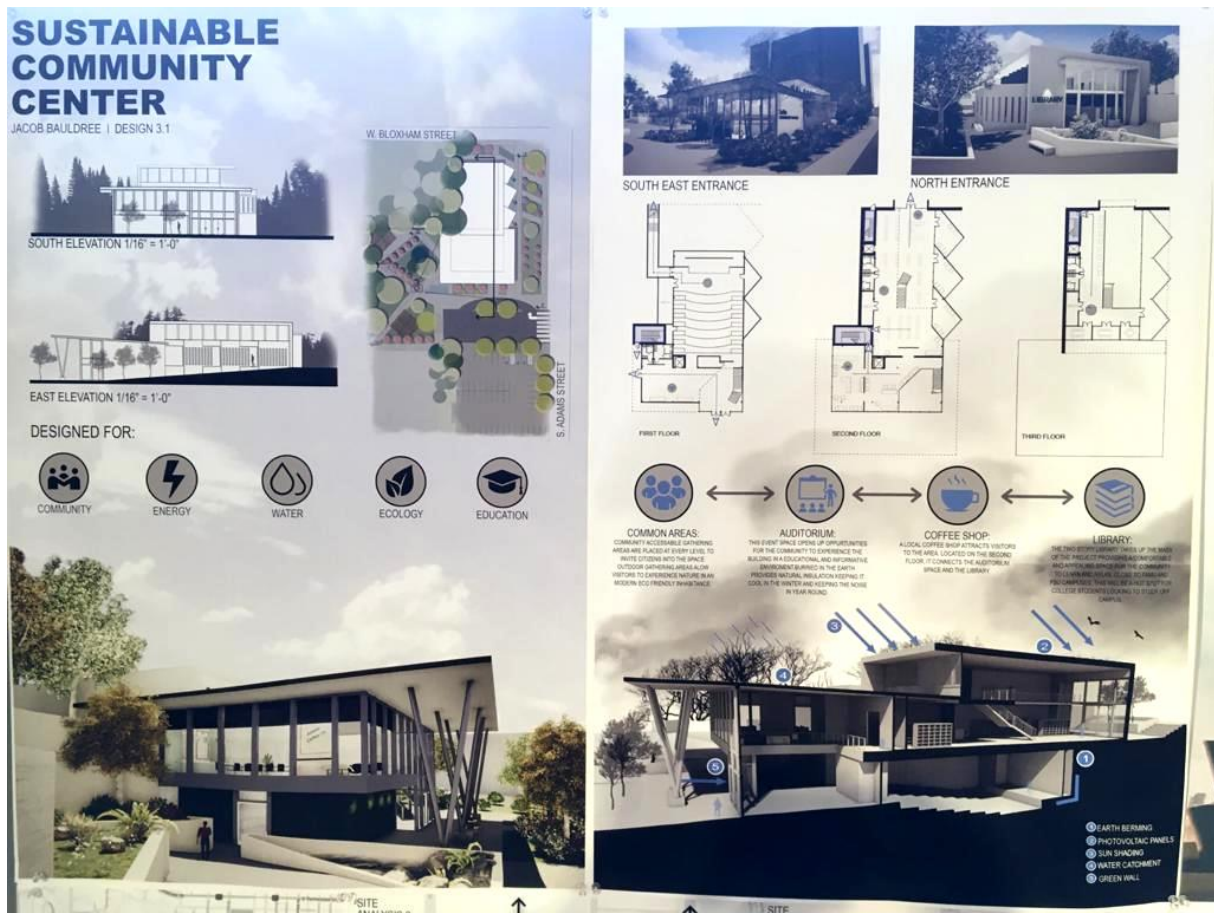


Fig.2 Jacob Bauldree, 3rd year Bachelor, FAMU Tallahassee, eco-responsible design conception.

### 3. Working hypothesis

Now that the limits of our work have been identified, we need to distance ourselves from the thematic attractors that disrupt our global vision. We do not wish to start a competition between the hand/brain pair and machines, nor do we want to develop a competition between humans and machines in the design process. That topic has been largely studied in other research works and becomes unproductive as it does not define what we are trying to design. Our argument, as explained thereafter, aims to define the needs and to observe at what moments machines become inevitable. Connected to that first attractor, the second one is the primacy of drawings in design. Jean-François Coulais recalls that “nowadays, we often consider the practice of drawing and the architectural design process as two inseparable entities, ever since antiquity.” (Coulais, 2014, p. 75). The third attractor considers software programmes as a simple tool that does not predetermine neither the design method nor the result. One only has to look at AD Magazine’s 2020 selection to make up one’s mind, whether it concerns the Axel Springer’s Headquarters by OMA in Berlin, the Audemars Piguet Museum Workshop by Bjarke Ingel BIG in the Vallée de Joux, Switzerland, or the Nanjing Zendai Himalayas Center by MAD Architects and Ma Yanso in Nanjing, China. Again, the result or the style should not be mistaken for the generation or design process. Moreover, we should not generalise based on exceptional creations, considering that the everyday production does not look similar. However, it is risky to think that the tool, and thus the materials, does not influence the design process and the final production. The last attractor that requires caution is BIM as a synecdoche of digital tools, and sometimes of architectural production. As mentioned earlier, BIM defines a new turn in the practice of the project, the organization of agencies and the definition of new skills required for the proper conduct of operations. BIM replicates the computerization that took place within agencies right before 2000, with the same forced resistance and adoption phenomena.

To establish this state of affairs, we started from an inventory of the major tasks, recognized by education as skills that need to be mobilized to analyses, imagine, design and build an architectural project. For each task, we studied at what moment they appear in the curriculums of the schools of Nantes and Tallahassee. We then questioned the recurrence of the task, i.e. its punctual or structural use. Lastly, we studied the use, or not, of digital tools to carry out the task. Two groups have emerged naturally: one involving representation and fabrication, and the other involving data manipulation.

### 3.1 Methodology

To carry out this study, we began by making an inventory of available courses by year, by subject. In addition, we interviewed fellow teachers. For FAMU, the work was facilitated by the fact that one of the co-authors of this article is also the director of programmes. For the second co-author, it was necessary to interview colleagues and confirmation came from documents circulated for the drafting of the HCERES (High Council for the Evaluation of Research and Higher Education) report which will allow the evaluation of the school. For the FAMU, the software inventory is relatively easy to establish as it is highly regulated. The choice is made by the Directorate of Studies and the dispatching is done afterwards. The typology of renderings is also relatively standardized and also responds to skills demanded on the job market, even very early in the studies. The Formit / Illustrator combination appears in the first semesters, then Rhino / Revit in the rest of the course. With the addition of Enscape, we have the tools that are mostly used in Tallahassee. For ensa Nantes, because of the size of the school and the breakdown of the tools learning between workshops, specialized courses and self-training, the inventory is much larger. It starts from a common base Sketchup, Autocad, then diversifies with Revit and Archicad, and integrates Twinmotion and Lumion for rendering and real time. Grasshopper is added from the 2nd year and a plethora of specialized software for structural and thermal calculations and for cartography. The mastery of computer tools in Nantes is reputed to be quite good.

### 3.2 Table 1: Representation, Fabrication-Modalities of legacy

The courses in the broadest sense have been inventoried and then organized by year and by progressive differentiation of what can be done identically by hand to what requires the use of dedicated software exclusively. This inventory gradually revealed two families, one responding fairly well to the modalities of legacy, while the other illustrates the modalities of emergence.

	Description	Années ENSA Nantes					Années FAMU Tallahassee			
		Licence 1	Licence 2	Licence 3	Master 1	Master 2	Bachelor1	Bachelor 2	Bachelor 3	Bachelor 4
Représentation, fabrication	<b>As-Builds</b>							Rhino		
	Recurrence									
	use of Digital Tool									
	<b>3D Conceptual &amp; massing drawing</b>	Analogique / Sketchup					Formit Rhino	Rhino		
	Recurrence									
	use of Digital Tool									
	<b>representation of 3D geometric shapes</b>	Rhino	Rhino					Rhino		
	Recurrence									
	use of Digital Tool									
	<b>2D technical drawing</b>	AutoCad					Formit Rhino	Rhino		
	Recurrence									
	use of Digital Tool									
	<b>3D technical drawing (BIM)</b>		Revit / ArchiCad					Revit		
	Recurrence									
	use of Digital Tool									
	<b>image composition</b>	Analogique Photoshop	Photoshop	Photoshop			Illustrator	Illustrator		
	Recurrence									
	use of Digital Tool									
	<b>3D realistic rendering</b>		TwinMotion / Artlantis					Enscape, Lumion, Twinmotion		
	Recurrence									
use of Digital Tool										
<b>presentation formatting</b>		Indesign				Illustrator				
Recurrence										
use of Digital Tool										
<b>VR, AR, Immersion</b>				Unity / Unreal	Unity / Unreal	Gravity Sketch/ new				
Recurrence										
use of Digital Tool										
<b>Digital Fabrication</b>	laser cutter	AutoCad / Sketchup		Grasshopper	Grasshopper	laser cutter	Formit, Rhino, Revit			
Recurrence										
use of Digital Tool										

Fig.3 Table 1: Representation, Making: Legacy modalities.

The first table reveals clearly that each task can be carried out either analogically or digitally. Both options are no longer competing in architecture schools. Instead, they are concurrent, with the students having the choice to use one medium or another depending on their skills, the relevance to the project or the professor's advice. Only the practice of virtual reality belongs solely to the digital world and can create a real gap. In Nantes, it is marginal and taught very late. In Tallahassee, it is introduced from the first year, with the underlying premise that the students coming to the school are already familiar with these tools and techniques thanks to video games. Introducing virtual or augmented reality from the first year disrupts every



argument on the relationship between hand, tool and brain, as we are already able to design, with natural gestures and in a representational space, forms, organizations on all scales with a visual and almost physical result for every decision. The first table shows a very good anchoring of new skills when they are offered in the curriculum, as well as their permanence during the training. Apart from readings and descriptive geometry, the skills are considered as necessary.

### 3.3 Table 2: Identification, importation, data management, emergence modalities

The second table highlights the real stakes of digital tools in education and in the practice of projects. All the tasks that are identified depend on the one hand on data that need to be identified and organized. On the other hand, they require extensive processing to integrate them to projects. There are two main ways to carry out the tasks appearing in the table: they either emerge after the formal reflection and correct missing points in the project in terms of acoustics, insulation, statics, etc., or they emerge before or during the reflection to develop the forms. In the second case, the complexity and the mass of data to process simultaneously makes the use of digital power indispensable to identify not the solution, but a set of solutions among which the design will choose.

An interesting point to observe is the fact that the tasks raise two problems that are connected. The first one deals with the students' skill to carry it out. Once the skill is acquired, one could imagine that it would maintain itself like the ones identified in Table 1. However, this is only a rare occurrence since, and that is the second problem, other competences are required to measure its realization. The evaluation skills are twofold, as one needs to be able to measure the good conduct of the process (is the question well formulated, is the data well identified, do the results cover a relevant field?), and one needs to be able to measure the set of solutions that are proposed, and perhaps the selected one.

Identification, gestion, importation, exploitation de données	<b>Data mining and management</b>									
	Recurrence									
	use of Digital Tool									
	<b>BIM</b>			Revit / ArchiCad				Revit		
	Recurrence									
	use of Digital Tool									
	<b>Structural calculations</b>									
	Recurrence									
	use of Digital Tool									
	<b>Daylighting analysis</b>		Sketchup		Sketchup				Revit	
	Recurrence									
	use of Digital Tool									
	<b>Energy analysis</b>			Solene						
	Recurrence									
	use of Digital Tool									
	<b>Acoustic analysis</b>				Catt Acoustique					
	Recurrence									
	use of Digital Tool									
	<b>GIS, mapping</b>			QGIS	QGIS					
	Recurrence									
use of Digital Tool										
<b>Parametric design</b>				Grasshopper	Grasshopper					
Recurrence										
use of Digital Tool										

Fig.4 Table 2: Identification, management, import and processing of data, modalities of emergence.

## 4. Conclusion

Our analysis will extend to other schools in and out of Europe. It aims to show that the reflections on the place of digital tools in architectural education, and by extension in the practice – if we assume that architects can blossom in emerging practices – revolve around the identification of new or complex tasks for which the use of machines is uncontested. Such tasks have long been given to experts who have gradually weathered the hegemonic position of architects in order to frame them, as it is the case for the Anglo-Saxon model with the structural engineers and economic engineers. However, for some tasks, such as the understanding of weather or energy events, or in economy of construction, sustainability issues are clearly questioned.

We proposed two concepts in this paper: legacy and emergence. Table 1 describes precisely what we can identify with the concept of legacy, which deals with the dissemination of architecture as it has been done since the opening of architecture schools. The concept of emergence, which is more visible in Table 2, describes not only new practices but also starts almost mechanically a dialogue with the social environment in which the project is embedded. By integrating data management, i.e. fine-tuned knowledge about the territory, as early as the design phases, we compel everyone to integrate the objectivation forms of weather and social phenomena, which will be included in the outline of the project. The point has thus translated from design forms that put digital tools or the hand in competition to design forms that include a large number of interacting data, for which digital tools are very useful.

In terms of education, the stakes have moved as well. Beyond the evaluation of a result produced by a student, the professor must henceforth be attentive to the process carried out by the students, which allows them to get feedback both on the process

and the production. This distinction also allows for a better identification of new forms of architectural practice, and for the invention or reinvention of tomorrow's profession.

We would like to thank our colleagues who have commented on the tables to improve them.

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