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Report on integrated practice

Suggestions for an integrative education

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Changes in the profession of architecture inevitably place pressure on architectural education. One would think it is a straightforward supply and demand system – skills should be taught in school to meet the needs of the profession. Yet the maturing process for architects is slow, expertise is hard-earned, and it is not always obvious how "input" in school will result in "output" many years later. It is far more appropriate to consider architectural education as the beginning of a life-long process of inquiry rather than as a direct input/output mechanism. It is acknowledged that education must meet the needs of the profession. But education's most important role is to shape the trajectory of exploration after graduation, thus contributing to the future of the profession.

Software that allows for the three dimensional construction of a virtual building (Building Information Modeling or BIM), will increasingly influence project delivery and the interactions between architects and other stakeholders. BIM, plus the new way of working it engenders, generally known as "Integrated Practice," will necessitate changes in education, but the exact nature of the shift is unclear. Already curricula in some design studios, professional practice, and construction classes are evolving. With the increased attention on BIM software, and its increased availability to students, we are likely to see BIM permeate (if not dominate) the studios within the next few years. However, careful attention must be paid to the impact of this particular tool on the curriculum. It is tempting to add BIM to the list of things students must learn immediately upon entering school, but serious concerns are raised by introducing such a sophisticated tool at a foundation level. So too can we question delaying exposure to what is arguably the most powerful medium available. We must ask: what role should BIM have in architectural education and where is its appropriate place in the curriculum? But before even considering these questions, one must examine how education can establish trajectories for BIM in particular and more broadly, for Integrated Practice.

The promise of Integrated Practice is vast—one can imagine having the power to control a wide range of information related to the project, full collaboration with a range of stakeholders, and virtual rehearsal of construction. To fulfill this promise, practitioners must shift the way they think and work. There are promising experiments[1] into ways of working that challenge traditional practice in pursuit of all three elements of the tripartite goal—better, faster, and cheaper; but an evolutionary leap in design thinking—commensurate with technological advances—is sorely needed. There is an urgent and immediate need for architectural education to prepare future practitioners who will catalyze this change.

1 FOGA, SHoP, Lazoroffice and KTA are among the firms that are trying a variety of production and project delivery structures that begin to challenge conventional circumscribed roles of architects in the design and construction process.

Other than a few pioneering professional practice and construction courses, recent innovations in architectural education have largely focused on formal skills needed to succeed in design. The design studio has frequently succumbed to the seduction of new forms or reinterpreting established formal compositional principles. For students fluent at generating form in a variety of media, possibilities raised by new production methods are largely unexplored; ephemeral factors such as time or light remain invisible in the design process; and the underlying logic of the representation software is poorly understood. This essay seeks to establish principles for a holistic reinvention of architectural design curriculum – a curriculum that can produce practitioners who will capitalize on emerging opportunities to truly transform both design and construction.

The reformulation of the curriculum outlined here focuses heavily on the areas most affected by BIM: representation, design, construction, and practice. Though the scope of these suggestions lacks the breadth needed in a holistic architectural curriculum, they form a useful starting point to discuss BIM in education. In order to evaluate any model for future architectural curricula, one must first understand the changing professional context of representation tools and have an understanding of current and past curricular structures.

BIM aptitude

Principal among current transformative representation tools is Building Information Modeling, a tool that allows data to be linked to each element within a three-dimensional model, and to evaluate the performance of the model as a whole. All representation tools—digital or analog—affect the design process, and leave their mark on the built form. The potential effect of BIM on the design process is unprecedented, and the ease in which it can translate directly into built form can equally be viewed as exciting or alarming.

Never has a representation tool been so demanding of its user. The competent BIM operator must have an understanding of the tool, knowledge of materials and construction methods, and appreciation for professional practice. However, to move from "competence" to "excellence," I would add to this list perhaps the most important aptitude – critical thinking: the ability to simultaneously envision multiple aspects of a problem and their relationships before proceeding toward a solution. The premium placed on this skill certainly pre-dates the arrival of digital tools, but BIM creates an exigent demand for this way of thinking. In contrast to the other qualifications listed above, this particular ability must be developed before entering practice as is best honed during an academic architectural education.

BIM, like other more familiar media, organizes information in a graphic or visual format. What sets it apart is the extent in which information is interconnected in often invisible ways. In these early days, BIM's value is most clearly seen in projects that are not easily envisioned – those with complex geometries or demanding building systems. In the future, BIM should help us see beyond formal complexity to manipulate ephemeral conditions such as acoustics or lighting. One can imagine a rich set of parameters evaluating design options linked to user behavior, local construction conditions, market pricing of materials and labor, maximal effective climatic response, and a host of chronological issues.

Primary among architects' complaints about 2D CAD programs is their inappropriateness to the "sketchy" early phases of design – phases in which a lack of specificity is actually a productive part of the design process. There is a great deal of attachment and mystique associated with the loose sketch done on the back of a napkin. Whether on a napkin or on a monitor, architects value this stage because one's mind remains open to consider several alternative possibilities simultaneously. Many three-dimensional modeling tools offer a way to visualize design ideas that are later fleshed out or exported into other formats for development. Much of the value in these models lies in their ability to foster the germination of design ideas without forcing premature decisions regarding details not yet known.

The Building Information Model should theoretically make it possible to meld the sketchy design stages with production oriented building documentation. Though outwardly appearing more fixed and determined than CAD (BIM models can look like highly developed "products" after only a few hours of work), in certain ways the BIM environment can support an iterative, open-ended process. BIM's malleability allows operators to propagate a single change throughout all the linked elements and views in real–time. As information is added or changed, the line between schematic design and construction documentation is blurred.

A critical caveat must be noted: for architects to exploit the potential of BIM as an iterative design tool, they must be retrained to perceive fluidity in what looks fixed (or at least to resist this perceptual bias). The turn of the century poet Paul Valery tells us that "seeing is forgetting the name of the thing one sees", in BIM, it is exceedingly difficult to forget anything. I would assert that superior quality design is best supported when architects can see beyond what looks fixed, to ask fundamental questions rather than following a process based on assumptions.

For instance, when considering an opening in a wall, questions as to the opening's fundamental nature need to be asked: is it an interruption in a wall system, a gap between two walls, or a part of a rhythm of apertures? In BIM, the opening is immediately labeled as "window": its dimensions, placement, and thermal performance can be assigned, its "family" of elements, (glass, window trim, sash, sill, mullions, header) are linked together. Its "level" ties it to a particular datum height, so changes in any of the elements are updated automatically.

Though flexibility in changing specific elements is infinite, the linkages between elements become increasingly difficult to alter as the density of data increases in the model. Questions regarding the nature the opening tend to no longer be asked. The label of "window" has become impossible to forget. It is not intuitively apparent that one way of "seeing" the opening (the particular way that its level and family are associated) might lead to a smoother design development process than another. Mistaken assumptions can be disastrous in BIM, as bad associations become inextricably bound into the model. Teaching students to distinguish between assumptions and speculation will reveal the true strengths and weakness of BIM as a tool for envisioning and testing design ideas.

Ironically, for a client or contractor, the highly realistic nature of the BIM model, coupled with its capacity to make changes in real-time, can be enormously empowering – allowing them to visualize many more possible configurations than they could have without the tool. In the hands of an experienced architect, BIM is an effective communication tool with which they can interface with clients and contractors. In the profession, BIM's value in substantially advancing the ability to communicate is undeniable, but it remains an incremental improvement. To achieve transformative advances, the power harnessed by BIM must be wielded in a different manner.

Actual/Factual

It is difficult to explain the difference between "problem solving" and "design thinking." Simplistically, one could say problem solving is a relatively low-level skill, used in pursuit of a correct or optimal answer. Design thinking requires the designer to pursue multiple, lateral options simultaneously, with the goal of defining the questions rather than seeking answers. Of the two, design thinking is more demanding to learn and far more demanding to teach. Pessimists say that the emphasis on teaching design thinking has been eroding for many years, and that BIM only threatens to accelerate its demise. One cannot help but sympathize: using BIM, it is easy to be overwhelmed by data and reduce architectural design to a simple a matter of problem solving, albeit at a highly complex level. What would be so bad about a generation of architects that competently solve problems? Le Corbusier made a distinction between construction that meets basic needs and architecture which touches the heart. I would maintain that construction can be achieved through problem solving, while architecture requires design thinking.

Two historical analogies illustrate past relationships between question-driven and answer-driven systems. In the 17th century, scientific instruments were categorized into two types: mathematical and philosophical. The principal distinction being that mathematical instruments measured or demonstrated the known (such as a sun-dial), while the philosophical tested or discovered truth (like air pumps that created vacuums for testing electricity produced by friction). Almost three centuries later, the artist and Bauhaus educator, Josef Albers, viewed the world as divided into "factual facts" and "actual facts" – factual facts being finite and objective, actual facts being open-ended and raise questions for further study.

By applying these taxonomies to the situation at hand, I propose that currently, BIM is treated as a factual/mathematic instrument when our goal should be to use it as an actual/philosophical apparatus. Architectural education must contribute critical ingredients to this alchemy.

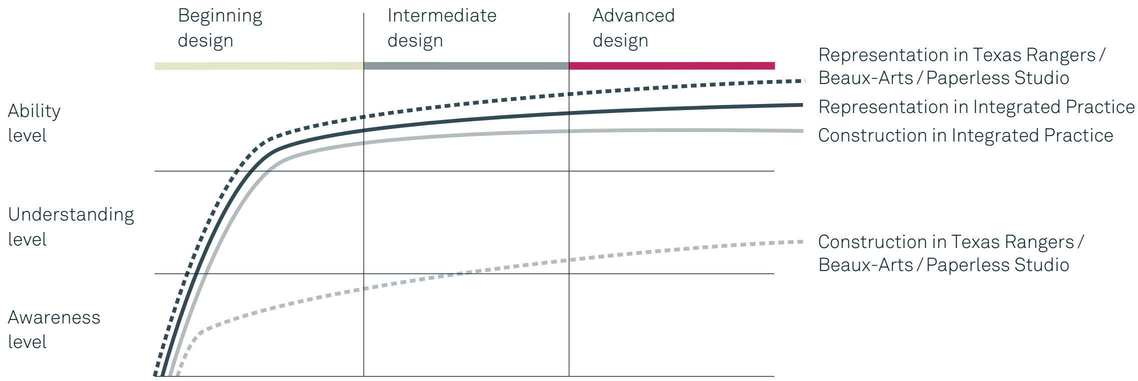
To further extend Albers' definitions, factual facts derived from the BIM process can be seen as the data that architects incorporate into their digital models—material properties, costs, details, construction techniques etc. Actual facts can be seen as the ways to think about that data—the information we gain as a result of manipulating the model. These actual facts will only be apparent to those with the ability to think critically about data, design, and representation. Albers believed that, through well-applied imagination, some factual facts could be turned into actual facts. It is in this area where academic training can make significant contributions. The measure of success for architectural education in the future, will be the extent to which graduates can first distinguish actual facts from factual facts, and in their ability to perform the necessary transformation from factual to actual.

		Gothic Master Builder	Ecole des Beaux Arts	Bauhaus	Texas Rangers	Paperless Studio	Integrated Practice
Representation	Proportioning system	Moderate	High	Moderate	High	Not addressed	Not addressed
	Formal composition	High	High	High	High	High	Moderate
	2D Drafting	High	High	High	High	High	Not addressed
	3D Modeling	High	Moderate	Moderate	High	High	High
	Stereotomy	High	Moderate	Not addressed	Not addressed	Not addressed	Moderate
	Descriptive geometry	High	Moderate	Not addressed	Not addressed	Not addressed	High
	Rendering	Not addressed	High	Moderate	High	High	Moderate
Construction	Construction materials	High	Moderate	High	Not addressed	Not addressed	High
	Construction sequences	High	Not addressed	Not addressed	Not addressed	Not addressed	High
	Understanding of manufacturing process	High	Not addressed	High	Not addressed	Moderate	High
	Ethics & professional practice	High	Moderate	Not addressed	Not addressed	Not addressed	High

High proficiency
Moderate proficiency
Not addressed

The nature of architectural curricula

Looking at seminal curricular models across the history of post-17th century architectural education, one can track the varying degrees of emphasis placed on skills related to the representation of design ideas, as opposed to those related to the understanding the actual making of a building. **see Figure 1 ↗** **Though widely separated in time, and operating in vastly different contexts, one can identify certain affinities between the curricula of the Ecole des Beaux Arts, the Texas Rangers and the Paperless Studio regarding their emphasis on formal composition and de-emphasis on building construction as a source of design inspiration. The Bauhaus and the future Integrated Practice Studio could be similarly grouped by their emphasis on materiality and manufacturing processes.**



Essential to this reading of educational trends is linking content with timing in the curriculum. Figure 2 ↗ Attempts to plot the expected level of sophistication, against time in the curriculum roughly divided into beginning, intermediate and advanced levels. The grouping of Beaux Arts, Rangers, Paperless Studio can be said to place early and very high expectations on formal exploration and representation. The study and documentation of construction systems is introduced much later, and with less depth and emphasis. Practice issues are virtually invisible. In contrast, the Bauhaus keeps formal and technical knowledge on more or less parallel tracks – slowly developing them in tandem over time. Practice is similarly neglected. The Integrated Practice model is by far the most demanding – requiring the integration of construction, practice and formal knowledge early and at a high level. In this context, formal composition becomes only one of several emphases and the least urgent and demanding of the set.

A key element missing in the generalizations suggested by these simplified diagrams is training in “design thinking”—that ability to discern actual facts in the world of factual facts. This could arguably be said to be the Holy Grail of architectural curricula across eternity, but its timing and content is difficult to track. Successful curricula in the past found ways to provide this training while responding to their particular historical, social and professional contexts. The careless introduction of BIM with all of its prerequisite skills to a curriculum could overwhelm the subtleties inherent in nurturing design thinking—displacing it from its central role in the architectural curriculum.

Viewed skeptically, one could say that the Integrated Practice curriculum is impossibly taxing, placing demands on students that can simply not be met. Many educators worry that design thinking will be jettisoned to make room for new content. Not only is there competition for students’ time but there are two competing philosophies: BIM is inherently answer-driven, design thinking is question-driven. The fear is that heavy emphasis on “how to” guarantees a loss of the critical “why.”

While the curriculum needs to be protected against this threat, in other ways, BIM provides a refreshing shift. The most positive effect of BIM on the curriculum will be the de-emphasis on formal manipulation. This change could cause architectural education to take on a far more relevant role in the world – dealing with richer and more substantive issues than aesthetics alone. Shape grammar explorations begun in the 1970’s and the current interest in algorithm-driven form generation developed since the early 1990’s are intellectually provocative and aesthetically compelling but, as pursued today, seem to continue a form-centric trajectory that may no longer contribute to architecture’s future. This is not to deny the inherent potential of computationally translating data into form. For example, algorithms could be linked to construction, material or sequencing constraints, and which in turn could systematically transform the building model according to rules grounded in dimensional or gravitational reality. In this way, form and space can remain central concerns of architectural design, but can be explored in ways that incorporate precise consideration of other, equally important, areas.

Trajectory

If form-centric curricula have become outmoded or self-indulgent, and a BIM-centric construction/practice agenda threatens to expropriate time needed to train design thinking, is there room for a new trajectory? Content, format, and sequence of curricula necessarily varies according to an individual program's contexts and strengths. It is difficult (and probably inappropriate) to recommend any curricular change that could be applied to all schools. I will attempt instead focus attention on two main categories of issues: those that deal with the nature of BIM as a representation tool, and those that respond to the professional expertise demanded by its use in Integrated Practice.

1 Slowing down BIM

Students should know what drives their tools. Understanding the inner workings of BIM can be accomplished by choosing software that encourages the user to tinker with parametric codes (such as Generative Components or Digital Project). However, these programs have notoriously steep learning curves, even for digitally facile designers. A more appropriate way to teach these lessons in school might paradoxically come from low-tech, traditional analog processes: descriptive geometry, physical models, and rigorous design editing.

Descriptive geometry requires students to grapple with the flatland of the page while constantly keeping three-dimensional geometry in mind. The simultaneity of generating multiple views from fixed positions fosters supple spatial comprehension. Like the parametric relationship of points in a model's database, points on the page become mentally associated to other points in other views. For instance, the projection of a shadow created by two intersecting forms onto a shaped plane requires the translation of one point through several geometric operations. The visual/spatial understanding of these intertwined relationships lays the groundwork for understanding (and exploiting) parametric linkages that go beyond geometry.

Building a BIM model has similarities to building a physical model. With models, the manner in which they are constructed matters. A take-apart model whose roof can be removed to reveal a floor plate reads differently than a model of the same building which can be split open to reveal its section. The exercise of physical model building remains a powerful design tool, and can illuminate the process of modeling with BIM. Alternation between the haptic feedback of an analog model and the digital manipulation of an electronic model provide complementary learning experiences – the media is different, yet both processes necessitate design decisions during the process of their construction.

In addition to mastering geometry and understanding the implications of the way models are constructed, students should develop a rigorous process of establishing associations between elements. Students should understand that elements of the model might be linked, not only because of building conventions, but also for reasons of design intent. For example, construction priorities would dictate that all windows (and perhaps doors) are grouped into a family of elements, and can therefore be manipulated (changed, priced, built) as such. However, design priorities might dictate that a specific opening be linked to a specific orientation, or that a room's south-facing windows be linked to a target luminosity in that room. It is important to note that the act of sorting out all of these priorities is a challenge in and of itself. There are two kinds of skills needed: first, the ability to generate options by systematically testing combinations of design factors, and the second, arguably more important habit, is to edit these options using highly developed skills to establish priorities – recognizing some relationships are more productive than others.

It is difficult to achieve transparency in a tool as powerful and complex as BIM. Marketing of 3D modeling software has historically been primarily feature driven. The increasing capabilities of the software often came at the expense of usability or intuitive clarity. Upon its release, SketchUp was enthusiastically received as an alternative to other more complicated 3D modeling programs because it was more accessible and appropriate to the needs of beginning design students. In this spirit, a stripped-down version of BIM is needed. The most obvious solution is a simplified version of a current BIM program, or alternatively enhancing an existing accessible 3D modeling tool.

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2 Practicing practice

Professional education is responsible for preparing students to grapple with the challenging issues faced daily in practice: costs, codes, material assembly, and collaboration. Among the most potent ways to teach these issues is sometimes called project-based learning. In this type of teaching, practical issues must be carefully constrained, incrementally built up, and always linked to design decisions. Given the increased demands on the curriculum as a whole, strategically targeting project-based learning in key areas is needed. There are two curricular areas in which BIM seems particularly suited to offer the greatest opportunity: building construction and collaborative practice.

It may be indisputable to say that architects with greater knowledge of material and construction are better able to design with BIM than those without, but does the reverse corollary hold true: does using BIM enhance one's knowledge of construction? Default libraries within proprietary programs such as Revit, provide conventional assemblies that can be inserted into the model as the design progresses. Familiarity with a compendium of standard construction types may assist the user creating a collage of building components, but does not necessarily lead to a deeper understanding of building construction.

Conventional and logical construction systems are readily available in the default libraries and settings in BIM. However, when one looks carefully, critical gaps appear. For example, making an open or revealed corner from a panelized system requires one to override the default assumption in Revit that joins the corner into one material system.[2] As one might expect, the program is only as intelligent as the operator. A door might look credible in the model but have no room for framing, trim, hardware or swing. The appropriate educational context in which to introduce BIM may be a construction systems course, but one in which construction logic is rather than copied and the limits of the software are made clear.

Much has been made of BIM capacity to return the architect to the role of the "master builder," the central position among a diverse team of experts. Architects functioning in this way must be able to listen well, synthesize information from a range of sources, balance a variety of needs and agendas, and elicit the best work out of each contributor, while always advancing the design intentions. Collaboration in its professional sense is hard to simulate in an academic setting. Professional collaboration forms among participants who have clearly defined (and complementary) roles, responsibilities and expertise. Collaborators come to the table with experience and maturity gained over many years of practice. It is difficult to create a facsimile of these conditions in an academic setting. Yet it is possible to teach collaborative ways of working if success is measured less on outcome (the primary achievement in practice) and more on process (a way of working that can be taught in school).

The informed give and take commonly found in practice can occur in school if conditions are right. Studio conversations that most closely parallel the language and tenor of professional collaboration occur in settings where teams of students are working at full scale. This scenario is most commonly executed as a full semester or year-long design/build studio but more contained exercises can also be effective. The power of this type of education has been proven in several successful models.[3] Among the many skills students learn is to work with each other and integrate information from fabricators, expert consultants and community members – the essentials of collaboration.

The suggestions in this section have covered design and representation issues raised by BIM and those building construction and collaborative practices to consider in preparing students for Integrated Practice. To capture the full richness of architectural education, the conversation must expand to include critical topics such as history, theory, site/urban design and socio-cultural issues, etc. This essay is intended to serve as the beginning of dialogue among academics and between academics and professionals – a discourse vitally important to the future of the profession.

2 This particular shortcoming was addressed in Revit 9.0 where the default is to separate the planes. I am indebted to Marilia Rodriguez for sharing her experiences as project architect on the Loblolly house, the first all-Revit project in the KTA office.

3 Including the Rural Studio (Auburn) and Design Build projects led by Professor Mary Hardin (University of Arizona)

Conclusion

Regardless of the magnitude of BIM's eventual of impact on the profession, its recent rise provides the ideal catalyst for rethinking architectural education. The level of expertise required to intelligently design with BIM is significant, and serious consideration must be given to how it can be taught. Looking back, even the most admired architectural curricula never attempted to cover all the skills and knowledge that a mature architect should eventually have. Today, this is even more true given the level of complexity and specialization in the profession – and of course, the new demands of Integrated Practice.

In this context, it is more important than ever for educators to hold to a strategy that prioritizes a few "actual facts" over the infinite number of "factual facts." Ideally, time should not be spent on facts or skills which are quickly outdated, but instead focus should be placed on the underlying logic behind those facts and skills.
In this way, students learn ways of seeing and thinking that will sustain themselves throughout a long career in an ever-changing profession. In future curricula, core design skills will remain extremely important, yet new demands must be anticipated.[4] The difficulty will be developing a cogent set of courses and exercises that encourage the habit of asking questions rather than seeking answers.

If BIM is introduced in the curriculum without respecting its considerable liabilities, design thinking will not survive. Now more than ever, this way of thinking and seeing should be valued – it is architects' most sought-after expertise. A year ago, the architect James Cutler claimed, "There's nothing more capable of making my employees stupid than AutoCAD, because they can draw something two-dimensionally and it looks right to them, but they're not seeing three-dimensionally." While it would be hard to fault BIM of this particular shortcoming – one can easily fear a future where BIM has effectively made us too stupid to question the rules and assumptions we are meant to control.

4 In a similar retrogressive vein as my advocacy of descriptive geometry, I would also call for the re-introduction of figure drawing in the curriculum.

This relatively straightforward exercise provides the most expedient demonstration of the importance of proportion and clarify relationships between positive and negative space.

What's next?

Information must be made available to the right people at the right time. Manufacturers' information should be fed to designers in real-time as they choose materials and set dimensions. Modular algorithms provided by manufacturers could be added to CAD applications, these tools could provide feedback as materials are incorporated into building models. It should be clear during the design process if, for example, a dimensional adjustment to a cladding system would result in more efficiency in manufacturing, assembly or performance. Ideally the feedback loop would work both ways, allowing input from designers to affect the manufacturing process. One could imagine that the most frequently requested customization of a system could lead to its becoming a "stock" item, thereby lowering costs and production time for a superior design. Other productive loops can be imagined between architects and contractors, allowing field assembly information to be incorporated into the design and vice-versa.

Information must be available in the right format. Future media should be transparent – having minimal interference in the translation of architectural idea to building model. There are two representation issues that need to be addressed: compression of data to iconic notation and enriched physical interfaces. Currently, associations between elements are invisible or indexed as tabulated numbers. These associations need to be graphically noted in some fashion (icons, colors etc.) that allows them to be part of the visual language of the building model itself. As a layer of graphically depicted information, associations could be manipulated alongside representations of physical elements like walls, windows and floors. The physical interface that designers need is highly visual, simultaneous and should, ideally, engage the body. Large display systems and pen-style input devices are two developments that could begin to achieve the type of interaction that is needed. The "heads up" display incorporated in combat aircraft is perhaps closer to the ideal – where the model, data and controls could be displayed in parallel and manipulated by touch, gesture or speech.

Having more information does not make us smarter, in fact large quantities of unfiltered information can overwhelm us. However, having the right information at the right time in the right format can make us better designers – informed, adept, and able to deliver better projects more efficiently.

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