EXPLORING LEARNING OBJECTIVES FOR DIGITAL DESIGN IN ARCHITECTURAL EDUCATION

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ABSTRACT: What are the objectives of teaching digital design in architecture? While this seems a rather primitive inquiry it in fact is loaded with misunderstanding and disagreement. This paper aims to bring accepted educational research about learning objectives into the discussion of digital design's relationship to architecture. In particular, Bloom's Taxonomy is introduced and referenced as a tool for creating clarity, transparency, and accountability among educators. The purpose of reflecting upon learning objectives for digital design in architecture is not to produce a definitive list of what students ought to learn. Learning objectives are written for specific curricula, student needs, and faculty interests. They are useful because they provide a clear definition of expected outcomes and which becomes a point of dialogue. In order to evaluate something, it first must be named. Through evaluation and discussion, a discipline develops. When Bloom created the learning taxonomy, this was the goal. Not to explain or lay claim to how students must learn, but to provide a shared structure so educators could compare their approaches. In a similar manner, creating and sharing learning objectives for digital design instruction, using established tools like Bloom's Taxonomy, can produce a more organized dialogue about how to align the use of digital tools with the core values of architectural education and the development of the discipline itself.

1 INTRODUCTION

1.1 *Introduction*

During the past 25 years, the introduction of computing and other digital machines into architecture led many schools to consider and make changes to their curricula and courses. However, there is little agreement within architecture departments, much less between schools, on what it means to design digitally, what it means to teach it well, and how this integrates with more traditional methods and understandings of architectural design.

This problem is aggravated because much of architectural education today is what Bruner calls "folk pedagogy", guided by implicit assumptions but not connected with educational theory or evidence beyond one's experiences. (1996) As such, there have been few attempts to to apply peer-reviewed curriculum design strategies and instructional methodologies to the challenge of digital design instruction in architectural education.

In response to this challenge, this paper proposes that defining learning objectives for digital design in architectural education, in connection with established educational and learning theories, can create a productive dialogue and a starting point for evaluating and addressing the challenges of integrating digital design.

1.2 *Pedagogical Alignment and the Value of Digital Design*

The lack of agreement and clarity among schools regarding digital design creates problems for the discipline. How can a skillset be taught without a clear definition? And how can the field evolve when there is such contention over education in a critical area? Dialog and common ground are needed.

A key reason for the confusion surrounding digital design instruction in the university setting is a misunderstanding of its educational value as a set of skills beyond technical skilling. In architecture schools, there tends to be a cultural hierarchy that places significant importance upon studio courses as sites where skills are integrated and practiced, and less importance upon supportive technology courses (such as a digital representation course) where those skills are first learned. However, this hierarchy ignores much about how learning functions and how effective learning takes place. A more nuanced understanding of the relationships between digital skills and design processes is needed.

One of the most significant effects of educational research has been to redefine the scope and goals of learning. Decades ago, before the development of contemporary learning theories, schools emphasized developing core skills such as reading and memorizing information such as dates and facts in a history class. The implicit assumption was that this level of learning was sufficient for students to write reports, solve problems, and produce other sophisticated applications of literacy. However, while many students could demonstrate ability at, for instance, providing the correct solution for a specific type of word problem, educational researchers found that students rarely understood what they had learned, nor could they easily apply their skills and strategies to new contexts. (Clement, 1982) The students knew their lessons by rote and adapted to succeed at their instructor's tests, but they had a superficial understanding of the material. Today though educational models and expectations have evolved, digital technology is often relegated to this type of learning.

While skills and facts remain important to learn, the goal of education today has been restated: to provide students with a foundation of deep learning and the intellectual tools to ask and address meaningful questions. (Bransford, Brown, and Cocking, 1999) In contrast to superficial learning of facts and procedures, deep learning entails knowledge of the underlying principles, domain structure, and strategies to activate skills and knowledge and apply them flexibly in a variety of conditions – particularly conditions which are different from the ones where learning originally occurred. Such as the translation of design thinking from an academic to professional context. Deep learning is what most instructors would recognize as productive and transferable learning yet few courses actually achieve. Architectural studios are examples of a deep learning environment.

In contrast to architectural studios, the current state of digital design instruction in architecture tends to follow an educational model which does not support deep learning. Presently, much of what students learn in technology skills courses is by rote: sequences of commands and procedures intended to produce reliable results. While students can operate software and other tools with what appears to be great fluency, the vast majority do not have a deep understanding of computing or digital media principles (Senske, 2014). As a result, their work tends to be inefficient and derivative. Like the school teachers in the earlier example, digital design instructors emphasize core skills for using digital tools and then expect students to apply them towards design projects. This is the reason a learning gap exists. First, students do not learn the tools with significant guidance to develop depth and rigor; second, they are not taught explicit strategies for applying digital methods to design tasks. Students often fail to develop an understanding of digital design methods because the pedagogy is not aligned with the goal of deep learning. This leads to a frequently cited criticism of digital design: work which is repetitive or uninventive because students are grappling with technology rather than controlling it. The technology does not make it this way – it is how it is used.

This assumes that such a goal is recognized in the first place. Learning digital tools is often seen – by students and faculty alike – as mere technical skilling rather than a way of thinking about design. Professional architectural accreditation (NAAB) in American schools uses a set of learning criteria which specify Ability and Understanding (NAAB, 2014). However, this set of criteria does not address digital design with any specificity. There is no agreement upon the value or content of a digital design education, and so student abilities can vary widely from school to school, and within academic units. Students are less inclined to develop a thorough knowledge of digital design because it is not universally considered a meaningful intellectual and creative pursuit. This not only hinders progress within the discipline, but, in practical terms, it affects the profession. Failure to recognize the principles of digital tools and structures of problems they address makes it more difficult for students to learn and retrain themselves in response to changing technology.

The educational model of the design studio is unique its approach because it has many elements which contribute to the production of deep learning, such as opportunities for synthetic learning, active learning, complex problem solving, and self-reflection and critique. This is precisely the kind of approach that would benefit specialized digital design courses. Unfortunately, the architectural design studio is often seen as one type of learning, while digital design, which is thought of as mere technology, is seen as another. This disconnection is due to a misunderstanding about digital design due to a lack of clearly-defined and shared pedagogical goals. The present situation in education has come about because the implied goal of digital design education is mere tool operation (which does not require deep learning) when the expected outcome should be increased agency and sophistication of design ability.

One way to address the problem of pedagogical misalignment is to develop learning objectives for digital design. Learning objectives have the benefit of being a structured, well-understood, and research-based approach to curricular development. This method informs clarity and represents an explicit way to connect the goal of deep learning with pedagogical execution.

2 LEARNING OBJECTIVES

2.1 *Learning Objectives for Digital Design*

The idea of a learning objective is straightforward, but often misunderstood and misapplied. A learning objective is a specific statement which describes what a student will know (knowledge) be able to do (skills) as a result of engaging in a learning activity. A learning objective must have three parts: a measurable verb associated with the intended cognitive process, the necessary condition (if any) under which the performance is to occur, and the criteria for measuring acceptable performance (this is often implied). A simplistic example of a learning objective that fits this pattern is: "Given a set of contours the student will be able to generate a topographic model." The condition is having a set of contours and the implied measurement is an acceptable model. Learning objectives are focused solely on student outcomes and do not specify methods or other expectations for the teacher. They are not an attempt to create uniform classroom procedures or hinder instructor creativity through standardization. The teacher has flexibility in their approach, so long as the performance criteria are met. Learning objectives are useful because they help instructors with course planning and the creation of content. Furthermore, the explicitness of properly-constructed learning objectives establishes a basis for student assessment as well as the evaluation of teaching and curricula (Anderson, 2002). A primary challenge of digital architecture evaluation is the lack of criteria and therefore a lack of agreed upon traits for which to evaluate whether digitally produced code, drawings or images are successful.

In this manner, learning objectives support better learning and provide a common framework for schools to organize their efforts at improving education. For this reason, many Universities have standardized their syllabus policies to address learning objectives [see (Vanderbilt, 2016) and (Carnegie Mellon, 2016) for example]. The use of learning objectives may seem obvious or unnecessary if one is only considering their use in one's own syllabi, but in terms of disciplinary alignment, digital design instruction could benefit from the additional clarity offered.

2.2 *Bloom's Taxonomy*

A useful tool for developing better learning objectives is Bloom's taxonomy. The taxonomy is a hierarchical framework intended to help instructors coordinate their planning and assessment using a common language (Krathwhol, 2002). It represents the process of learning from acquiring simpler to more sophisticated thinking skills. The general idea of Bloom's taxonomy is that lower levels of cognition support higher levels. For instance, one must understand the difference between different methods of constructing a surface (comprehending) before choosing which surface to use (applying).

In its revised form, Bloom's taxonomy lists six levels of cognitive processes:

1 Knowing: memorization and factual recall
2 Comprehending: understanding the meaning of facts and information
3 Applying: selection and correct use of facts, rules, or ideas
4 Analyzing: breaking down information into component parts
5 Evaluating: judging or forming an opinion about the information
6 Creating: combination of facts, ideas, or information to make a new whole

A more recent addition to the discussion of the taxonomy is the inclusion of types of knowledge. Anderson and Krathwohl addressed criticisms of the taxonomy by recognizing that not all knowledge is equal in complexity and that knowledge tends to be developed from concrete (facts and concepts) to abstract (procedural) and finally to knowledge of one's own cognition (metacognitive). (2001) In concert with cognitive processes, the knowledge dimension of the revised taxonomy enables a more nuanced discussion of learning objectives. For instance, under the newer version, the taxonomy does not progress and stop with creating, but also includes thinking about one's learning progress and how one creates.

Bloom's taxonomy has been criticized because it does not represent the complex and interconnected nature of cognition (Furst, 1981), but the taxonomy was never conceived of as a model or theory. Nor is it a prescription for every course to follow. One could design a course with at least one learning objective at each level. Depending upon the skills required, some levels may need additional objectives. Students with different abilities may be able to begin learning at higher levels. The value of the taxonomy is less that it represents exactly how learning works or that it tells instructors how to teach, but rather in how it helps to organize and align pedagogical thinking.

Educational frameworks like Bloom's taxonomy are not in common use in architectural education. The reason for this is unclear but may derive from a disciplinary resistance to self-articulation. However, for those developing or revising architectural curricula, having access to a set of learning objectives that uses the taxonomy can enable a dialog within the discipline, with other disciplines and educational researchers.

Bloom's taxonomy helps support the goal of developing deep understanding in digital design instruction. One way it accomplishes this is by establishing the basic cognitive processes involved in learning to design thoughtfully. To see all of these steps organized and consider them with respect to digital design is to shed light on what is often an opaque practice. The taxonomy makes it clear that one does not just use or not use various tools, but one must understand them, choose from them, and evaluate those choices as part of a design process. In this manner, an advantage of learning objectives developed through Bloom's taxonomy is that they can elevate student outcomes towards higher-order thinking. (Biggs, 1999) For example, without the proper outcomes articulated, a student might submit a design, but was merely applying a procedure. Bloom's taxonomy makes it clear that creation depends as much on understanding one's decisions (the "why") as knowing the correct commands (the "how" – which is often students' focus). For teachers and students alike, Bloom's taxonomy helps clarify that the goal of digital design instruction is not only to learn how to use digital tools, but to apply them towards better designs and more sophisticated design thinking.

With regards to teaching methodology, the clarity of learning objectives derived from Bloom's taxonomy can help motivate qualities of student performance which are often lacking in digital design courses, such as innovative solutions and well-crafted, thoughtful representation. As mentioned in the previous section, many learning objectives are not specific enough, sufficiently measurable, or targeted to student's learning level. Bloom's taxonomy can help ensure that students are practicing the skills that they should be learning in their activities and at an appropriate level of cognition. This enables the pedagogical gap between learning digital methods and creating designs to be filled with deliberate (or mindful) practice.

Deliberate practice is a recognized process through which individuals train themselves to high levels of performance. Research has shown that learning of complex skills is most effective when students engage with tasks that are appropriately challenging, with clear performance goals and feedback, and sufficiently frequent opportunities for practice. (Ericsson, K.A., Krampe, R.T. and Tesch-Römer, 1993) The difference between merely making and deliberate practice is that a student monitors their progress towards a specific goal and changes their performance in response to feedback. The student continues to do so while increasing the challenge of the activity to further improve. Learning objectives assist students in deliberate practice by creating specific and appropriate performance goals which they can use to monitor their progress. This guidance directly supports the development of abilities on the highest (metacognitive) level of the taxonomy, which are crucial for sophisticated work and achieving transfer of skills and knowledge to other domains. (Perkins and Salomon, 1992) Thus, the notion of deliberate practice stands in contrast to the disengaged ways that many students learn and use digital tools, which is often oriented towards production for its own sake rather than for quality or thoughtfulness. Introducing deliberate practice is one way for schools to motivate deep understanding and to bring craft back into discussions about digital representation

2.3 *Creating and Teaching with Learning Objectives*

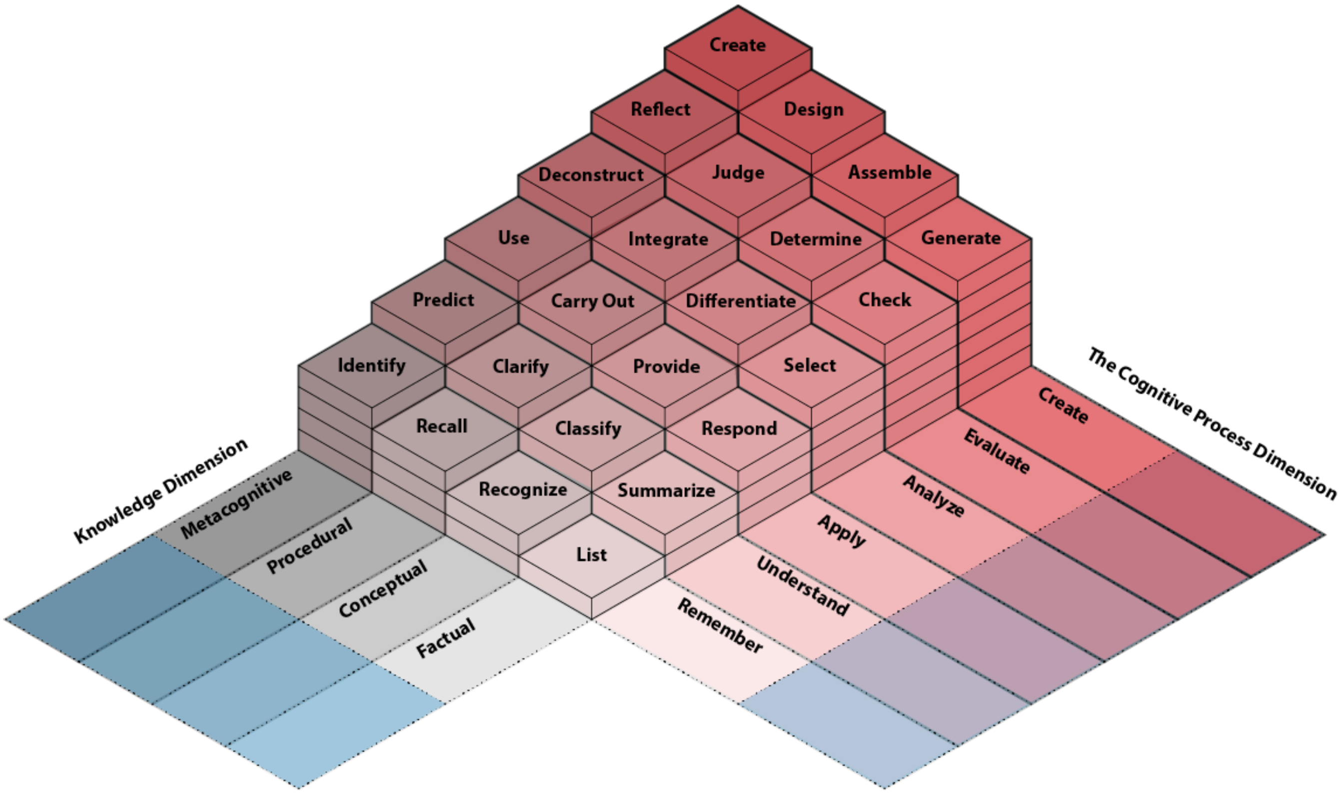
While many digital design courses have learning objectives listed in their syllabi, these are not often used correctly, in response to the findings of educational research. In this section, we propose several ways to make learning objectives for digital design more appropriate and effective.

First, many stated learning objectives do not take into account the learning process for developing complex skills and thinking. As mentioned earlier, traditional digital design pedagogy tends to emphasize learning through design tasks. The tacit learning objective of most activities, ostensibly, is to design something via digital methods. However, this does not acknowledge the steps involved to prepare students for design, such as learning about the tools, practicing methods, comparing and selecting methods, etc. These skills and knowledge are implied by the goal of designing, but by not stating this explicitly, the instructor might neglect teaching and assessing the constituent skills and knowledge that students need, but might not manage to learn on their own.

When developing learning objectives, it is important for digital design instructors to acknowledge how learning occurs as a developmental process. Creativity and autonomy, abilities exercised in design work, are higher order thinking skills. Higher order thinking is dependent upon requisite technical skills and other cognitive resources (Weiss, 2003). As such, these activities may not be beneficial learning experiences for beginner and intermediate students. Research shows the importance of matching learning objectives to student level (Klahr and Nigram, 2004). Novices benefit from direct guidance in basic skills and knowledge, while objectives for advanced students should emphasize synthesis and independence.

Second, many learning objectives for digital design instruction conflate activities and goals with learning outcomes. A goal is a statement of the overall intended outcome of a learning activity or course. Learning objectives are specific achievements which contribute to the goal (Ferguson, 1998). For example, a course description that says "students will be exposed to digital fabrication technologies" has presented a goal, but not stated a specific, measurable outcome. Likewise, a statement such as "students will fabricate a small-scale physical model" describes an activity, but does not provide enough information to discern what students are supposed to learn from the activity. A learning objective that addresses these issues would be: "students will use GIS data to generate a small-scale physical model using appropriate digital fabrication techniques." This objective presents a condition (GIS data), an outcome (the model), and assessment criteria (are the techniques appropriate? / is the model is correct?). Understanding the learning objective helps define the cognitive skill level of the activity and the appropriate assessment. For instance, if the objective was to learn about computing concepts, issuing a quiz with questions about procedures would not be a helpful measurement. To facilitate effective instruction, goals, activities, and learning objectives must be aligned with one another

Last, many learning objectives as presented do not support a means of formative assessment. Most courses only assign grades for projects, which are typically creative or design work. Again, these are higher order thinking skills and may not be appropriate to assess from novices. Grading project submissions does not give the instructor or the student much opportunity to remediate skills or knowledge that were misunderstood or not acquired. Moreover, feedback on a design artifact may not help instructors and students achieve the goal of deep understanding because it makes conceptual and procedural knowledge indistinguishable from the outcome. Studies have shown that ability to perform procedural tasks does not mean students are able to explain what they are doing or why. (Schoenfeld, 1985) This is not to say that instructors should never grade projects. This is appropriate when the intent is to assess creative work and problem solving, particularly from an advanced class. Learning objectives should measure the correct student outcomes for the level of the student and in a manner that allows students to respond with changes in their performance.



Bloom's Taxonomy 1956	Bloom's Modified Taxonomy 2001	Bloom's Digital Taxonomy 2007	Associated Skills	Digital Skills	Communication Spectrum
Evaluation	Creating	Creating	Designing, constructing, Planning, producing, inventing, devising, making	Designing, programming, filming, animating, blogging, mixing, re-mixing, wiki-ing, videocasting, podcasting, directing	↑ Higher Order Thinking Skills Collaborating Moderating Negotiating
Synthesis	Evaluating	Evaluating	Checking, hypothesizing, critiquing, experimenting, judging, testing, detecting, montoring	Blog commenting, reviewing, posting, moderation, collaborating, refactoring, testing	Debating Commenting Video Conferencing
Analysis	Analyzing	Conceptualizing	Comparing, organizing, deconstructing, attributing, outlining, finding, structuring, integrating	Hacking, mashing, linking, validating, reverse engineering, cracking	Reviewing Questioning Commenting
Application	Applying	Applying	Implementing, carrying out, using, excecuting	Running, loading, playing, operating, uploading, sharing with group, editing	Posting Networking Contributing
Comprehension	Understanding	Connecting	Interpreting, summarizing, inferring, paraphrasing, classifying, comparing, explaining, exemplifying	Boolean searches, tweeting, categorizing, tagging, commenting, annotaging, subscribing	Chatting E-mailing Twittering Texting
Knowledge	Remembering	Doing	Recognizing, listing, describing, indentifying, retrieving, naming, locating, finding	Bullet pointing, highlighting, bookmarking, group networking, shared bookmarking, searching	Instant Messaging Lower Order Thinking Skills ↓

Fig. 1 Bloom's taxonomy was first introduced in 1956 and since then has seen widespread use in instructional design. A revised version was issued in 2001, which changed the levels from nouns into active verbs, added the knowledge dimension, and placed creation (synthesis) at the top of the hierarchy of cognitive process (Krathwohl, 2002). More recently, Churches created a "digital" version of Bloom's taxonomy that updates many its application to computing activities (2004).

3 CONCLUSION

The value of learning objectives is not what they add to a syllabus, but rather how they prompt a larger conversation about educational and professional values and standards. Creating learning objectives for digital design in architecture exposes many implicit assumptions about what faculty believe about learning and the role of computing in the studio. At the same time, it raises the bar for architecture schools to consider digital design as more than merely learning to operate tools and software (activities which are not themselves valid learning objectives) and to instead connect these practices to design thinking and the development of architectural designs.

Bloom's taxonomy assists in framing this discussion about learning to design digitally by offering a structure of cognitive accomplishments for students. This helps re-align architectural educators away from frameworks derived from folk pedagogy and towards established theories and research into educational psychology and learning cognition. Instead of teaching and learning digital skills and knowledge through a hierarchy of the tool's features or increasing complexity, Bloom's taxonomy foregrounds processes of remembering, thinking, and judgment. These objectives are more closely aligned with deeper understanding and integrative mastery. This type of learning is precisely the antidote to the kind of superficial engagement one often finds in architecture schools that prompts negativity towards the use of computing in design.

The purpose of reflecting upon learning objectives for digital design in architecture is not to produce a definitive list of what students ought to learn. Learning objectives are written for specific curricula, student needs, and faculty interests. They are useful because they provide a clear definition of expected outcomes and which becomes a point of dialogue. In order to evaluate something, it first must be named. Through evaluation and discussion, a discipline develops. When Bloom created the learning taxonomy, this was the goal. Not to explain or lay claim to how students must learn, but to provide a shared structure so educators could compare their approaches. In a similar manner, creating and sharing learning objectives for digital design instruction can produce a more organized dialogue about how to align the use of digital tools with the core values of architectural education and the development of the discipline itself. Learning objectives are not only for evaluating one's students or teaching. They help departments and educators understand whether they are teaching the right things. The question should always be: "how does this improve design?"

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