Redesigning Housing and Rethinking Programs through Design-Build

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REBUILDING:
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Introduction

Traditional, stud-based methods of residential construction are not sustainable, from either an environmental or economic perspective. The resources embedded within this form of construction are generally poorly allocated, the materials used often cheap and, at times, toxic, and the methods deployed, inefficient. The resulting homes are resource intensive – a problem amplified by the fact that the resulting structures must be made livable through the continual infusion of non-renewable resources and most will have a sharply limited useful lifetime.

In order to investigate this concern further, several groups of students pursuing advanced degrees in architecture have, over the last two years, collaborated with experts in the fields of development, fabrication, design, construction and urban planning to, incrementally, revise the building delivery system used for affordable housing and making it more efficient, sustainable and affordable. Through this prolonged address, these students were able to bring together the efficiencies and supports of traditional construction with those offered by emerging materials and processes, including digital fabrication and parametric data analysis. The first home, HOUSE01, will be completed in the spring of 2017. Although not yet complete, early evidences are promising: the current bid for the construction cost of the kitchen and 1.5 baths for HOUSE01 is $10,000, roughly $17,000 less than the average cost of similarly scaled homes; the current schedule of production indicates a savings of over 21 days.

Based upon the insight earned through this effort, faculty and students are currently working with community partners to design and build HOUSE02. The intent in so doing is to further refine the building delivery process, more rigorously incorporating all techniques used in HOUSE01 and providing a proof of concept for the approach – all while providing students the support needed to demonstrate attainment of the learning objectives associated with the courses involved.

This paper will describe the pedagogical approach that results from this effort, documenting how students and faculty simultaneously satisfied the oft-conflicted demands posed by the long-term address required by the centralizing muse and the carefully regulated academic frame. It will outline how this precedent, in terms of both the structure of the learning environment and the insight generated through it, might indicate a direction by which we might not only reconsider the manner in which we teach, but the manner in which we educate engineers, architects and other creative professionals. Bearing this in mind, the writing is divided into three parts: part one outlines the growing financial and environmental cost of housing, which served as a centralizing muse for the course sequence; part two will describe the housing delivery process that supported these trends and served as the primary grounds for investigation within the courses; and part three will describe the approaches of learning and teaching that emerged from this investigation.

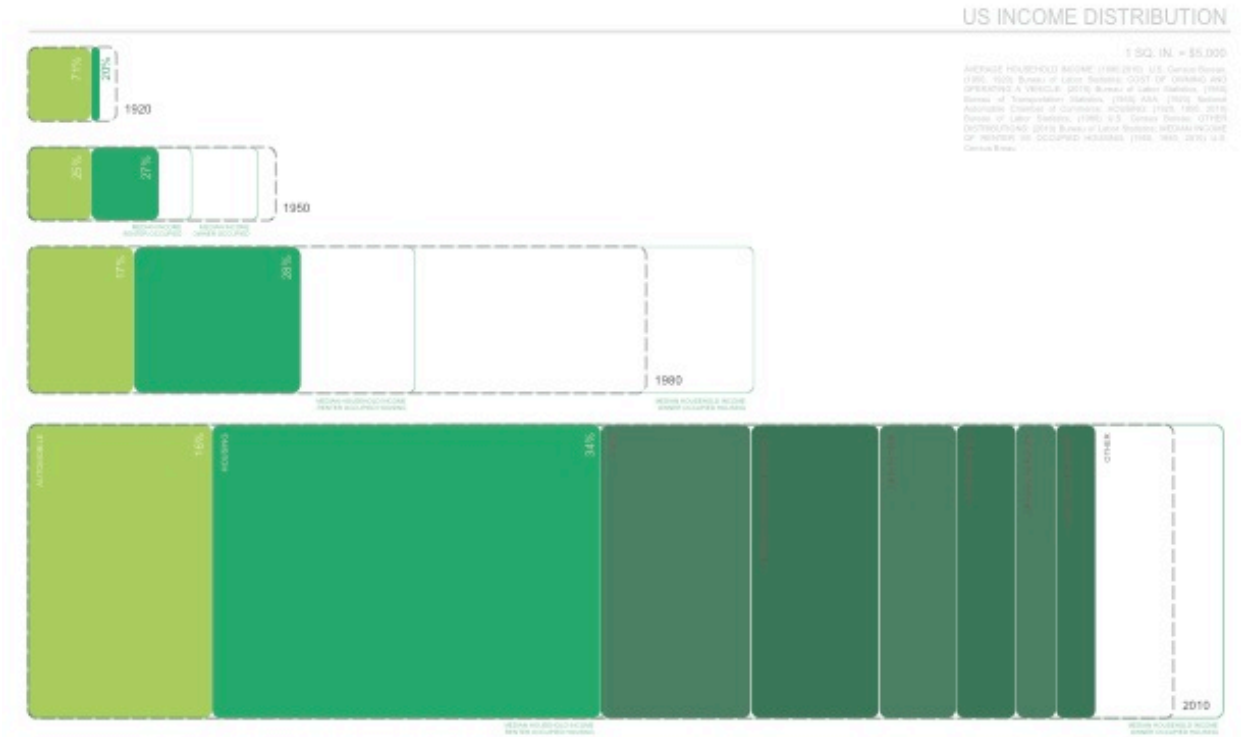
Part One: Reconsidering Housing

The Financial Cost Of Housing

In 1920, the average US home was 1,048 SF and cost $2,074; in 1950, the average US home was 983 SF and cost $11,000; in 1980 the average US home had nearly doubled in size to 1,740 SF and increased in cost to $47,000. By 2010, the average home was over 2,390 SF and cost more than $210,000. This results in a cost per SF of $1.97 in 1920, $11.19 in 1950, $27.01 in 1980 and $84.06 in 2010. As a percent of net monthly income, based upon the average income and interest rates at that period, a house in 1920 represented an investment of 20% of one's income, in 1950, 27.2%, in 1980, 27.5% and in 2010, 34.4%. Not surprisingly, the rising cost of construction has helped to curtail homeownership in the US, leading to relatively modest growth in this sector, with 55% of US citizens owning homes in 1950, 65% in 1980 and 67% in 2010.

Not insignificantly, if one performs the same audit of most other industries, a very different story emerges. For example, in 1920, the average automobile cost $1,084.00, or 71% of the average income, and 12% of US citizens owned a car. In 1950, the cost of owning and operating a vehicle was $1,080, or 25% of the average income, and 32% of US citizens owned a car. In 1980, the cost of owning and operating an automobile was $3,535, or 17% of the average income, and 68% of US citizens owned a car. And, in 2010, the cost was $12,509, or 16% of the average household income, and 81% of US citizens owned a car.[i]

If one projects forward these trends, it seems reasonable to postulate that our country has reached a plateau and may even see a decrease in the percentage of American homeowners over the next century, as well as a related increase in the percentage of renters. Although not altogether negative, this trend, which will place a growing number of homes in the hands of fewer and fewer owners, will likely lead to a significant increase in renting costs – a trend that has already started in many cities. As renting a home is, on average, between 250% and 400% more expensive per month than paying on a mortgage, this will likely result in an increase in the percentage of income spent on housing, which will impede not only the ability of renters to transition to owners – creating a growing class of dependent renters living within transitional communities - but also the ability of those renting homes to pay for food, clothing and other necessities.



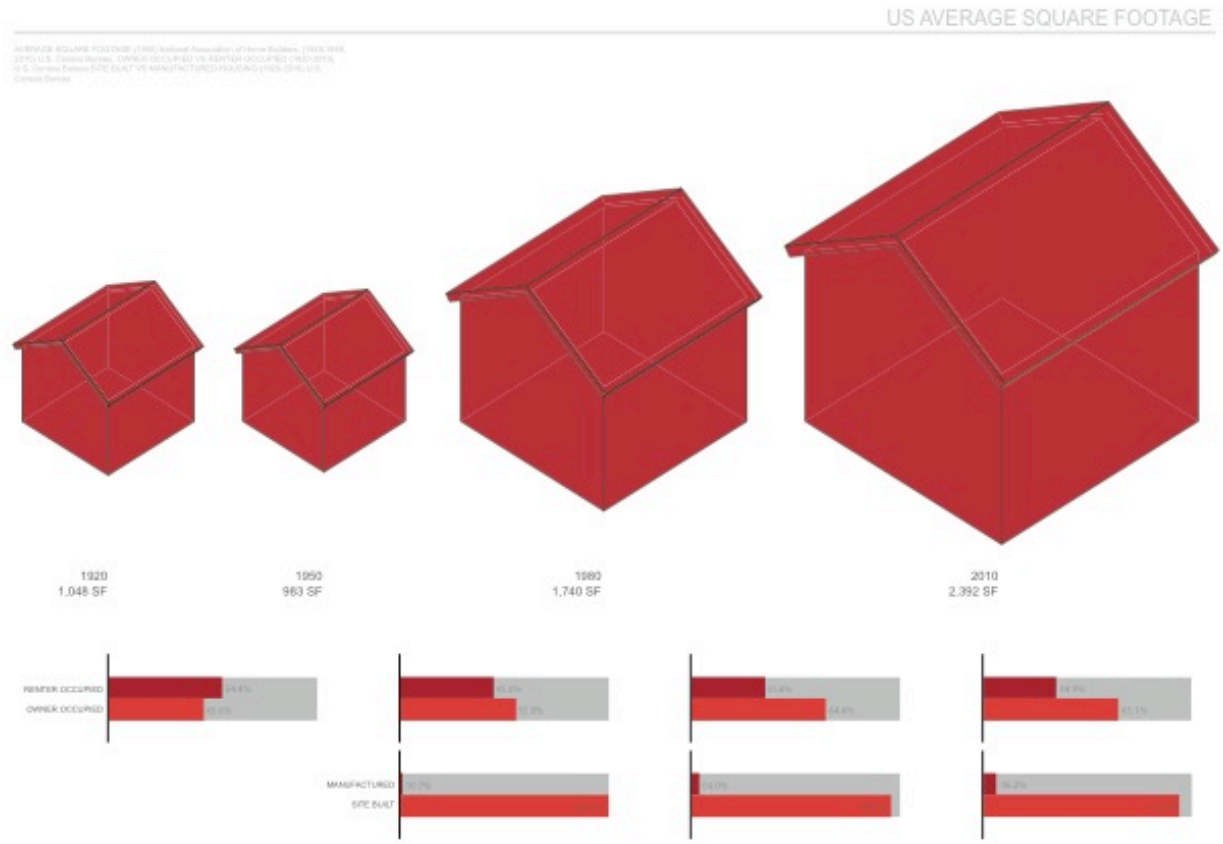
The Environmental Cost Of Housing

The environmental costs of housing are similarly sobering.

A recent study by the National American Housing Board found that "the average 2,000-square-foot home generates 1,500 to 3,700 pounds of solid wood waste and 1,000 to 1,800 pounds of engineered wood waste. Of this waste, three components — cardboard, wood and drywall — consistently account for 60-80% of the total on most job sites. These are fully recyclable materials."[ii] Unfortunately, the vast majority of these materials are not recycled or reclaimed, which is one of the reasons why the generation of construction and demolition debris far outpaces the generation of municipal solid waste. According to a 2014 EPA report 534 million tons of construction and demolition debris were generated in the United States – more than twice the amount generated by municipal solid waste.[iii] In response, the EPA has recommended a significant restructuring of the manner in which buildings, and homes, are designed, constructed and de-constructed.[iv]

Unfortunately, the contemporary building delivery system does not allow for these considerations, nor do the buildings produced through this process. The reason: the building delivery system is not a system at all, but loosely connected set of professionals, manufacturers and technicians, each of which has little influence over each other or the system at large. Thus, the building, and housing, delivery process only changes when each of these disconnected actors share a concern – as occurs when there are sizable shifts in market forces, a significant change in the political framework governing development or breakthrough innovations that cannot be

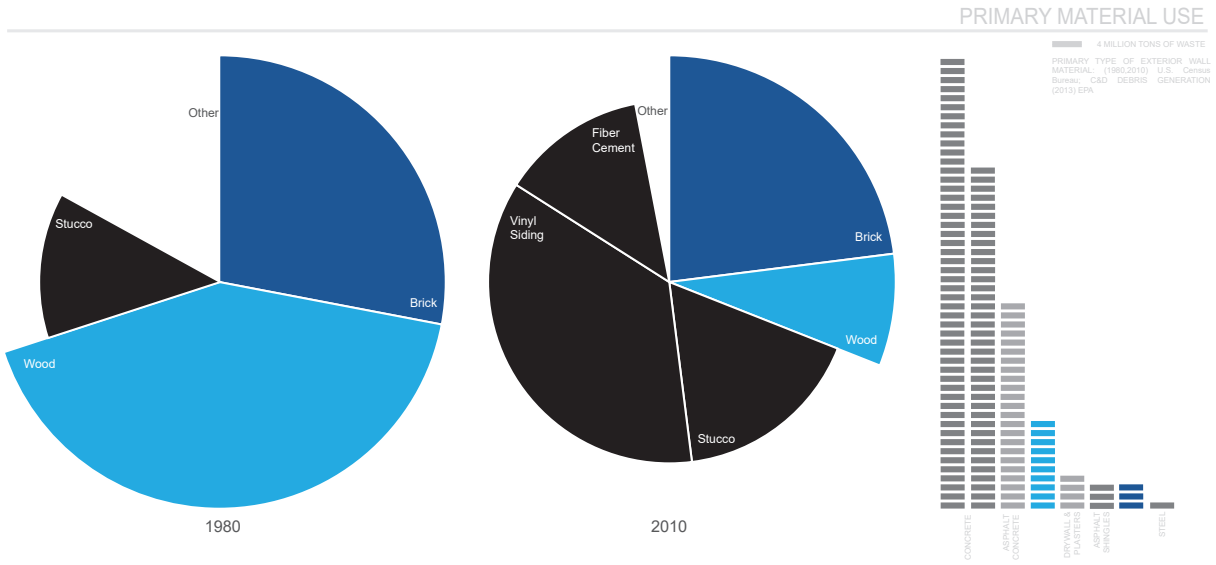
ignored. As these events are rare, the process changes little. Which explains why the average home takes the same amount of time to construct in 2010 – 6.9 months - which it did in 1980.



In contrast, the automotive industry over the last several decades has radically shifted the process associated with their products, making it more efficient and allowing the work produced to be more affordable, in terms of both initial and life-cycle costs, more effective, safer, and more sustainable. One can see similar trends in the production of furniture by IKEA, electronics by Samsung, and solar energy systems. To point, according to IKEA's annual reports, in 2016, 50% of the wood and 94.5% of the cotton used by IKEA, to produce all products, came from sustainable sources. In 2015, 88.9% of IKEA's waste was either recycled or energy recovered.[v] In 2016, Samsung was honored with two sustainability awards from the Environmental Protection Agency (EPA) and their Materials Management program including an award for the Galaxy S6 cell phone, which is 99.9% recyclable. In their sustainability report, Samsung claims to have had a cumulative reduction of 156 tons of waste since 2009 and has collected 2.26 million tons of waste products since 2008. These numbers are expected to rise to meet a goal of 250 million ton reduction in waste while collecting 3.8 million tons of electronic waste by 2020.[vi] California-based solar design and installation company, SolarTech, reports that,

between 2010 and 2013, the total amount of U.S. PV solar installations grew by 485% and the cost decreased by 50%. [vii]

So, while the cost of PV solar installations decreased by 50% in three years and Samsung will reduce the total waste produced by around 200% in ten years, home ownership and the process to create homes has remained largely unchanged for forty years, the cost, as a percentage of income, has increased by 47% over the last century and the waste produced by building construction and demolition is twice that of municipal solid waste.



<u>Part Two: Reconsidering Construction</u>

From these statistics, it appears clear that, in both economic and environmental terms, contemporary housing is not sustainable. Over time, this reality has a high likelihood of requiring a fundamental shift within the entire housing market – a reality that presents the architect and engineer with an opportunity to rethink the manner in which we construct upon and inhabit the earth.

Although the exact manner in which the housing delivery process must change is not yet clear, a number of principles that will likely impact this definition are quite apparent. First, and perhaps most importantly, the housing delivery system must be holistically reconsidered. Unlike current methods of production, which simply stitch together a sprawling array of products designed with a high degree of generic utility (so as to permit use within a wide range of scenarios), the reconsidered housing delivery system must design each component with an eye to the others involved in the construction, as well as the eventual and inevitable de- and re-construction of said work. This is much more in line with the process used to construct automobiles, cell phones and furniture – processes that account for, in great detail, the time and materials used throughout the fabrication effort.

This holistic definition of the process will permit greater scrutiny of it – a reality that will be supported by the second factor likely to define a revised housing delivery process: the growing and necessary impact of digital processes and toolsets within the design, fabrication, construction, de-construction, and re-construction effort. These processes, which record and retain the specific attributes of all components used and can assess the same in great detail, offer the designer a clear memory of the entire building delivery process, allowing the architect and engineer to constantly refine it. Properly documented and assessed, this should prompt an evolution in process, similar to those witnessed in other industries. Production times will decrease, as will material waste. The environmental and economic footprint will shrink.

This scrutiny will likely cause a re-conception of the components that go into housing, as well as a rethinking of how each of these components is conceived and fabricated. Parts of the home that support a great many functions – party walls, bathrooms, kitchen wet walls, structural envelopes – will likely take advantage of the incredible precision offered by digital fabrication while portions of the house that are relatively simple will take advantage of the savings embedded in modularity and repetition. The former will begin to model the approaches currently deployed in the production of Airstreams and airplanes, as described by the work of designers like Buckminister Fuller and Charles and Ray Eames, the latter will approach the production mindset found within curtain walls and IKEA cabinets, as described by designers such as Mies van der Rohe and Le Corbusier. Sections of the house that are likely to last for decades, such as foundations and building envelopes, will be reconceived as a part of a more lasting landscape, designed to harvest daylight and rainwater and enter into a more supportive and symbiotic relationship with the earth, while aspects that quickly lose utility will be designed to allow for simple replacement.

Part Three: Reconsidering Teaching

Mutable Tools

To prepare those entering the fields of engineering and architecture to contribute well to this more inclusive and considered process, educators must reconsider the manner in which we engage our students – a point which became clear as the authors guided students in their investigations into the situations described above. First, students must become better able to communicate productively with the other professionals involved in the reconsidered building delivery process – a list that includes, but is not limited to, real estate agents, investment experts, production engineers, environmental scientists, lawyers and community groups. Although seemingly a simple proposition, this need to dialogue with an expanding, and potentially shifting, assembly of constituents is fundamentally at odds with both the idiosyncratic terms and isolated processes oft-used by the architect and engineer, as well as the manner in which both professions have defined their value to the wider community.[viii] It is also at odds with the educational approaches that have trained students to enter into these fields, so defined. To broaden the conversation and establish a more inclusive dialogue, the educator must present professional knowledge, and the technologies and techniques upon which this knowledge is based, as a mutable tool, not one of fixed purpose. For, when knowledge is offered as a fixed entity, not to be questioned, it is brittle, incapable of evolution and, thus, unable to be in dialogue with

unanticipated partners or be developed so as to better address unforeseen situations.[ix] Although the value of this flexibility varies greatly, depending upon the specific skill or tool one is considering, perhaps the clearest example of this need for mutability – and a great place to start - is language. To quote educator, author and thinker Jerome Bruner, language is "perhaps the ideal example of one such powerful technology, with its power not only for communication but for encoding 'reality', for representing matters remote as well as immediate, and for doing all these things according to rules that permit us both to represent 'reality' and to transform it by conventional, yet appropriate, rules." Based upon this definition, Bruner postulates that the utility of language, and indeed all tools, rests "on the external resources of a grammar, a lexicon, and (likely as not) a supporting cast of speakers constituting the linguistic community."[x] Logically, if these communities are narrowly defined, as occurs when professionals deploy tools only appreciated by those within field, then so will be the potential role of said professional. If the communities are more broadly defined, through the deployment of tools that are relevant to and appreciated by a larger constituent, then the role of the professional will be similarly expanded.

What, then, does this mean for the educator? Primarily, it should direct those in education toward the creation of learning processes that encourage students to form tools capable of evolution. This requires that the educator eliminate any framework for learning that encourages a passive engagement of the subject, including those that privilege memorization and recitation over thinking and critical analysis. To once again quote Bruner:

"To instruct someone in these disciplines is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as an historian does, to take part in knowledge-getting. Knowing is a process, not a product."[xi]

Correspondingly, the educator must shift the act of learning from the lecture hall to the discussion group, from the classroom to the lab or studio, where students might be routinely challenged to engage clearly defined hypotheses and carefully structured dilemmas in a manner that demands not only the memorization and recitation of information, but its analysis, organization, creative deployment and, eventually, evolution. As observed by author and educator John Dewey:

"Knowledge that is fixed can only produce passive patterns of thought. The student may be able to recite the facts, but they will never be able to apply this knowledge to a problem that is not covered within their book. On the other hand, knowledge that is held in abeyance until its implications and voracity can be ascertained will become first active, then possessed, allowing the student to draw conclusions that would otherwise not have been possible."[xii]

Although there are tactics by which the educator might effectively translate the space of the classroom in order to achieve these ends, given the professional bias of many of these environments as well as the academics who help to define them, it is often more prudent to trade the classroom as a locus for learning for the greater landscape of practice – a landscape of assembly lines, wetlands, board rooms, highways, and neighborhoods. For, in so doing, the

instructor shifts the base of learning. Instead of offering students a translation of these critical landscapes that fits within the confines of the classroom, the educator provides students the opportunity to directly engage and interrogate specific aspects of their work within a more inclusive context. The resulting learning environment, provided it is structured in a manner that will encourage students to direct attention toward the engagement of specific course objectives and content, will compel the student to productively engage the broader content of their eventual work, including aspects that are simply not translatable to the classroom environment – a critical approach if one wishes to train professionals capable of addressing not only the thorny questions surrounding housing, but any contemporary dilemma.

Application, Not Acquisition

The resulting, more inclusive, dialogue will naturally bring into question the value of discrete acts of observation or experimentation, without clear regard to their implications. This, then, forms the second point of necessary evolution: encouraging the application of knowledge over its acquisition. For, if we believe that "learning is not wisdom" and "information does not guarantee good judgment," then the usefulness of any knowledge base is, arguably, tied to the length to which a student might apply it.[xiii] Or, stated another way, if the first point of evolution – to aid our students in the acquisition of translatable toolsets – shifts learning from the recitation of knowledge to the creation of translatable tools sets based upon this foundation, the second – to understand the implications of said toolsets – translates learning from the creation of translatable tool sets to their application. The first point provides an opportunity for our students to enter into a larger practice of study; the second encourages our students to develop the experience necessary to do this well. To quote Dewey:

"Because their knowledge has been achieved in connection with the needs of specific situations, men of little book learning are often able to put to use every ounce of knowledge they possess; while men of vast erudition are often swamped by the bulk of their learning, because memory, rather than thinking, has been operative in obtaining it."[xiv]

In this way, students are able to view acts of design and engineering holistically, including not only the construction of pre-determined tools, but also the implications surrounding this construction, as well as the attendant, and inevitable, de- and re-construction said tools. This prioritizes processes that move back and forth between exercises of analysis and synthesis, divergent and convergent thinking. Experimentation and testing within increasingly complex contexts becomes key, as do other processes that encourage "a constant tentative picking out of certain qualities", "a willingness to hold the final selection in suspense," and an ability "to reject the factors entirely or relegate them to a different position in the evidential scheme if other features yield more solvent solutions." The resulting educational frame encourages the demonstration of alertness, flexibility and curiosity and discourages rigidity.[xv] The attendant, and unavoidable, inefficiencies within the resulting learning process, although potentially frustrating to both the students and educator, are to be embraced, as one cannot push the student to develop the ability to judge, through careful examination and inquiry, the value and application of knowledge without it.[xvi]

New Frameworks

The third, and final, point of evolution is related to the conflict posed between the potentially lengthy process of synthesis and analysis described by the second point of evolution and the need, at least under current accreditation and university structures, to define the learning experience based upon pre-determined semesters and methods of evaluation that privilege quantifiable outputs or a behavior-reward model of interaction between student and educator. To address the former concern, educators must frame the exercises, projects, courses and curricula that define the logistical educational frame, in a manner that permits students to easily enter into pre-existing investigations, to move forward the inherited wisdom and then to clearly disseminate their findings so that the investigation might be extended in the future. Although aspects of this structure can be developed based upon the structures found within scientific inquiry or versioning and product development, these precedents are somewhat limited as they are largely supported by grant- or consumer-based funding models and are, thus, structured in a manner that prioritizes very focused inquiries and pre-determined points of dissemination. Directly applied to the classroom, these models can reinforce behavior-reward models of education and undermine the learner's creation, evolution and application of the toolsets, as described above. To find a more fitting precedent, the educator likely needs to marry these approaches with those described by contemporary techniques of crowd-sourcing – a model of dissemination, engagement and development that privileges the continual and structured engagement of a broadly defined (and much less pre-determined) constituent, the routine acquisition and incorporation of massive data sets and dissenting perspectives into the process, and a creative endeavor that depends upon the periodic and structured dissemination of work throughout its development. It is a call to supplement the creative process embedded in Microsoft with those offered by Linux.[xvii]

To address the latter concerns, regarding an over-reliance upon either quantifiable methods or behavior-reward models of education, one must complement learning objectives, outputs and measures that prioritize the acquisition of critical outputs with those that prioritize the demonstration of core attributes required within the process required to create them. This would marry an assessment of the professional toolsets produced within any given course, likely based upon its relevance, flexibility and potential impact, with an assessment of the student's demonstrated efforts in their production, especially as related to core attributes such as alertness, flexibility and curiosity. This will turn the attention of even those students focused upon achieving success based upon university-sponsored metrics toward achieving success based upon more encompassing concerns. Just as importantly, it will accomplish this without compromising the ability of the university to measure achievement in accordance with accreditation or structural demands. The impact of so doing is significant. To once again quote Jerome Bruner:

"it is doubtful, only, that satisfying states of affairs are reliably to be found outside learning itself – in kind or harsh words from the teacher, in grades and gold stars, in the absurdly abstract assurance to the high school student that his lifetime earnings will be better by 80 percent if he graduates. External reinforcement may indeed get a particular act going and may even lead to its repetition, but it does not nourish, reliably, the long course of learning by which man slowly builds in his own way a serviceable model of what the world is <u>and what is can be</u>."[xviii]

It is likely also critical to the health of the professions they represent, as well as the world framed by their efforts.

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[i] All statistics courtesy of the US Census reports for the time periods cited. US Census Bureau Reports 2010, 1980, 1950 and 1920, accessed January 9, 2017.

[ii] Statistics courtesy of the National Association of Home Builders, accessed January 9, 2017, http://www.nahb.org

[iii] Of the 165.6 million tons of building waste generated, 84.8 million tons is concrete (around 95% demo and 5% new construction), 37.3 million tons is wood (around 93% demo and 7% new), 13.6 is drywall (around 75% demo and 25% new), 12.0 million tons is brick and clay (around 98% demo and 2% new), 3.5 million tons is asphalt (around 95% demo and 5% new), and 4.4 million tons is steel (around 100% demo and 0% new). "Construction and Demolition Debris Generation in the United States, 2014" U.S. Environmental Protection Agency (2016), accessed January 9, 2017, https://www.epa.gov/smm/ studies-summary-tables-and-data-related-advancing-sustainable-materials-management-report.

Also, the "Advancing Sustainable Materials Management: 2014 Fact Sheet" full report indicates that 534 million tons of C&D debris were generated in the United States, in 2014—more than twice the amount of generated municipal solid waste – and that demolition represents more than 90 percent of total C&D debris generation, while construction represents less than 10 percent. Prior to adding C&D materials to the Advancing SMM Report, EPA examined the generation of C&D materials through separate studies. In 1996, EPA estimated that 136 million tons of building-related C&D materials were generated in the United States. By 2003, almost 170 million tons of building-related C&D materials were generated. In 2003, nonresidential sources accounted for 61 percent of that amount. The largest building sector that generated C&D materials was nonresidential demolition followed by the residential renovation." "Advancing Sustainable Materials Management: 2014 Fact Sheet", accessed January 9, 2017, https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials

[iv] Based upon these studies, the EPA recommends source reduction, giving it the highest priority for addressing solid waste issues. While reuse and recycling are important methods to sustainably manage waste once waste has already been generated, source reduction prevents waste from being generated in the first place. Examples of C&D source reduction measures include preserving existing buildings rather than constructing new ones; optimizing the size of new buildings; designing new buildings for adaptability to prolong their useful lives; using construction methods that allow disassembly and facilitate reuse of materials; employing alternative framing techniques; reducing interior finishes; and more." Environmental Protection Agency, accessed January 9, 2017, https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materialshttps://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials
https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials

[v] IKEA Sustainability Report 2015, accessed January 9, 2017, http://www.ikea.com/ms/en_US/img/ad_content/2015_IKEA_sustainability_report.pdf

[vi] Samsung Sustainability Report 2016, accessed January 9, 2017, http://www.samsung.com/us/aboutsamsung/sustainability/sustainabilityreports/download/2016/samsung-sustainability-report-2016-environment.pdf

[vii] Solar Tech Online, accessed January 9, 2017, http://solartechonline.com/blog/the-rising-affordability-of-solar-power-infographic/

[viii] A detailed description of how the architects have developed a need for patronage, as well as the related reliance upon idiosyncratic terms and isolated practices can be found in Margaret Crawford's writing, "Can Architects Be Socially Responsible?" Similar trends, often more pronounced, can be found within the processes used by engineers. SOURCE? Margaret Crawford, "Can Architects Be Socially Responsible?" in *Out of Site: A Social Criticism of Architecture*, edited by Diane Ghirardo (Seattle: Bay Press, 1990): 27-45.

[ix] Jerome Bruner, *Toward a Theory of Instruction* (Cambridge: Harvard University Press, 1966), 82-83.

[x] Bruner, 25-26.

[xi] Bruner, 72 (emphasis mine).

[xii] "If this meaning is at once accepted, there is no reflective thinking, no genuine judgment. Thought is cut short uncritically, dogmatic belief, with all its attendant risks takes place. But, if the meaning suggested is held in suspense, pending examination and inquiry, there is true judgment. We stop and think, we de-fer conclusion in order to in-fer more thoroughly." John Dewey, *How We Think* (Mineola: Dover Publications, 1997, first published 1910), 108.

[xiii] Dewey, 107.

[xiv] J. Dewey, 53.

[xv] "… a constant tentative picking out of certain qualities to see what emphasis upon them would lead to; a willingness to hold the final selection in suspense; and to reject the factors entirely or relegate them to a different position in the evidential scheme if other features yield more solvent solutions." Alertness, flexibility, curiosity, are the essentials; dogmatism, rigidity, prejudice, caprice, arising from routine, passion and flippancy are fatal." Dewey, 105-6.

[xvi] Dewey, 108.

[xvii] A detailed description of the development of Linux, especially as related to crowd-sourcing and open platform development can be found in James Surowiecki, *Wisdom of Crowds* (New York: Doubleday, 2004).

[xviii] Bruner, 127-8.