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Unplugging Inequality: Computational Futures for Architecture

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Abstract
In the 21st century, technologies like the Internet are commonly regarded as an empowering and uplifting force. With the broad availability of low-cost distribution channels, software development tools, and rapid prototyping machines such as 3D printers, the potential exists for nearly anyone to disrupt industries and find success. This optimism is mirrored in architecture, where, over the last 25 years, technologies such as CAD (Computer Aided Design), parametric design, BIM (Building Information Modeling), digital fabrication, and robotics have been a critical site of innovation, as architects seek to challenge traditional methods of designing and delivering buildings.

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Unplugging Inequality: Computational Futures for Architecture

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"The future is already here, it's just not very evenly distributed."
-attributed to William Gibson [1]

Introduction

In the 21st century, technologies like the Internet are commonly regarded as an empowering and uplifting force.[2] With the broad availability of low-cost distribution channels, software development tools, and rapid prototyping machines such as 3D printers, the potential exists for nearly anyone to disrupt industries and find success. This optimism is mirrored in architecture, where, over the last 25 years, technologies such as CAD (Computer Aided Design), parametric design, BIM (Building Information Modeling), digital fabrication, and robotics have been a critical site of innovation, as architects seek to challenge traditional methods of designing and delivering buildings.[3]

While many believe that technology is a way to create equality and provide opportunities, in practice this is not always the case.[4] Particularly in architecture, access to technology and knowledge about technology continues to be unevenly distributed, which can result in the perpetuation and intensification of existing inequalities. This paper highlights the issue of gender inequality with respect to technology in architecture. It identifies the current gaps in research, and proposes a series of methods for pursing technological equality in architectural education: clearly measuring inequality of technology distribution, democratizing access to technology, and improving introductory teaching of technology. What follows in this paper is the beginning of a research agenda rather than its culmination.

Technology is a broad term but used here to indicate those digital technologies specific to architecture. Discussions about technology in architecture are often concerned with its potentials and hindered by a constructed polarity between manual and digital, an outdated and futile fiction.[5] This focus on technique and media has distracted from a more politically and socially relevant dialogue about inequalities in beginning architectural education and its relationship to technology. While many types of inequality exist with respect to technology and architecture, such as race and class, this paper will focus on the problem of gender inequality. As technology is now essential to the practice and discipline of architecture, the ability to create with and shape technology is critical. In some respect, the lack of women specializing in design technology is unsurprising given that the practice combines fields that have historically been lacking in gender equity: management, information technology, computer science, and architecture. The goal of this paper is to reveal this dimension of gender inequality in architecture and architectural education and to begin to address it by moving beyond the anecdotal and into a constructive research agenda. This is not to ignore the history of intersectionality in feminist discourse but rather to create a well-scoped and focused analysis that can provide methodologies for future research.

Who Counts?

Architecture as a discipline, has been slow to fully acknowledge, incorporate, and integrate women into architectural practice and discourse. These past and present inequalities appear to be at work in the under-representation of women in technology. However, acknowledging the scope of the problem is difficult because, presently, specific data are not being collected about it in practice or in academia. To successfully argue for gender equality, detailed and accurate statistics are needed to move beyond anecdotal evidence. The current understanding of gender in architecture remains limited, as does our understanding of how women access and influence technology. One reason for this is the challenge of determining whom to study and how to measure. With regards to technology, how should participation be defined? As Gill Matthewson of Parlour writes, "It is easy to slip into anecdote and colloquial understandings of gender discrimination in architecture

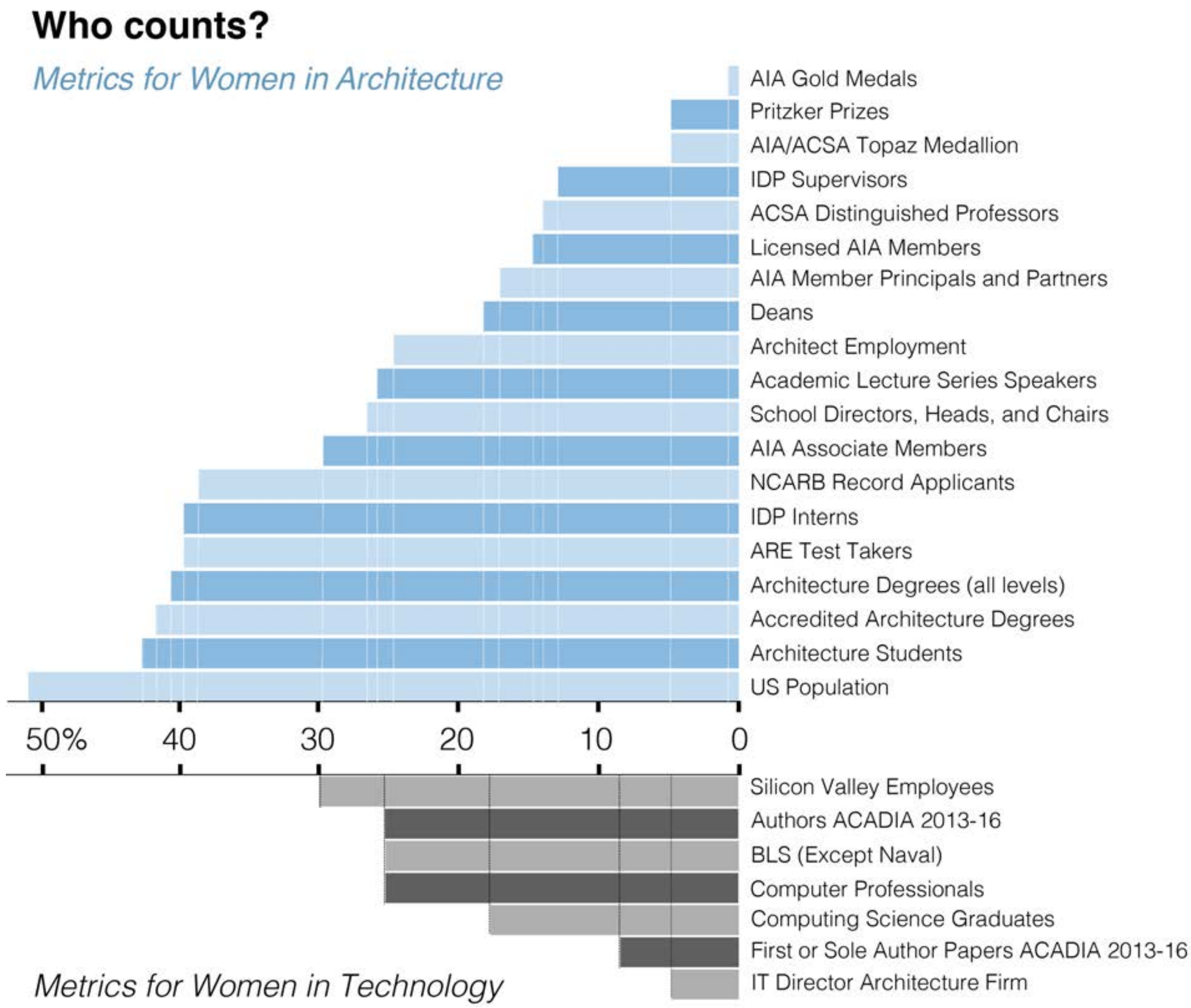

Fig. 1 Adapted by authors from the ACSA article 'Where are the Women?' Additional references are within the text. This is not a complete list of metrics but rather an effort to establish those metrics available to measure women in technology as it relates to architecture.

and much more difficult to parse out 'who counts'."[6]

The field of architecture recognizes its problems with gender equity, but accurately measuring the nuances of women's participation has remained elusive. The question of who is an architect and the extent of one's influence is not easily determined but is nevertheless crucial to combatting the lingering gender inequality in the discipline. For example, in 2013, 43% of students enrolled in NAAB-accredited architecture programs were female; 45% of architecture graduates were female.[7] NCARB's "By the Numbers" report reveals that 42% of 'record holders' are women[8], indicating an intention to pursue licensure, while the number of licensed women hovers around 18% in 2016 up from 9% in 2000,[9] but still far from parity as indicated by the 'The Missing 32% Project'.[10] These numbers differ from those of the US Bureau of Labor Statistics (BLS) which reported in 2013 that 25% of 'architects, except naval' were women.[11] The BLS data would also seem to indicate a dramatic loss of women in architecture, post-graduation, and low representation in the workforce, but the calculation of that total is complicated. Architecture is more than the profession and those who strictly practice within the profession. Many professionals who identify as architects are not counted in the BLS report: university instructors, urban designers, writers and critics, for example.[12] Taken-together, these numbers illustrate the complexity of the questions being asked about gender equality and the need to collect a breadth of data in order to paint a complete picture.

While, anecdotally, there seem to be fewer women than men in architecture, exactly how few is difficult to say with certainty. Once again, it depends upon how one counts. The averages of graduation rates and licensure only tell part of the story. At AIA firms, just 17% of principals and partners are women.[13] The percentages of women awarded the Pritzker Prize for Architecture and the Topaz Medallion for architectural education is even lower: both 5%.[14] These numbers indicate further inequality in the influence and recognition of women, which is disproportionate to their representation. Counting women is an important step in acknowledging and reducing inequality, but as a methodology, it has its problems and its limits. There are lessons to be learned and further questions to be asked.

As of this writing, there is very little data on the participation of women in technology within architecture. However, data from other fields suggest that women in technology is a broader issue and there is bias inherited from these disciplines when they are absorbed into architecture. In Science Technology Engineering & Mathematics (STEM) disciplines, gender inequality is a recognized and quantified problem. The problem is most acute in computing fields, and it is mentioned here for two reasons. First, the field of computing bears many similarities to the ways that technology is used in architecture. Developing and modifying computational software and systems for design has many parallels in computer science research and practices. Indeed, some of the training (learning programming, for example) is the same. Second, there is significant data collected by computing academics and professionals on the issue of gender diversity as well as research into how to address the problem. STEM data indicate that women are significantly underrepresented in computing. A 2013 report found that just 26% of computing professionals were women -- a percentage which is about the same as it was in 1960.[15] Women currently earn only 18% of all Computer Science degrees.[16] Indeed, it is the only STEM major to report declining representation of women over the last decade. This gender gap extends to academia and industry where research has found that 70% of authors on published technology papers are men.[17] At the same time, women represent only about 30% of the workforce in Silicon Valley.[18] Collection of this data has been an important step in helping to highlight and address this issue, though it has not led to gender parity in STEM.

Unlike the STEM fields, architecture has yet to acknowledge that its gender equity problem also extends to those who engage with technology. A reason for this could be that there is no direct evidence that such a gap exists; it remains an anecdotal circumstance. One metric that exists is the representation of women in technology publications in architecture. The authors' study of the Association for Computer Aided Design in Architecture (ACADIA) papers from 2013-16 found that 26% of authors were women. (This percentage is strikingly similar to that of STEM computing fields and professionals.) But only 8% of papers had women as the first or sole author. In academia, gender participation in technology is more difficult to determine. At our institution, while 49% of our architecture students are women, on average they make up only 19% of the students in digital technology electives and seminars. While the number of women participating in architecture is not at parity, the number of women participating in technology in architecture appears to be lower still.

The establishment of legitimate scholarship requires a problem first to have a name and, second, to be defined.[19] While many can share a story about women's work in architecture being disregarded, underpaid, or dismissed, it is presently much more difficult to quantify the use of technology by women in the practice of architecture. In this case, technology is used as a proxy for power in the architectural discipline and by measuring technology use the aim is to better understand the grain of women's participation in developing technologies.[20]

Gender Gap

Why are women under-represented in digital technology? Why does a technology gender gap exist? Once again, there is not much specific data available for architectural technology, but research in STEM fields has identified several possible causes which may parallel those in design and which may have been inherited by architecture in the transfer of knowledge and technique. In a speech given at the Grace Hopper Celebration of Women in Computing Conference, Susan Wojcicki (CEO of YouTube), summarized two important reasons women choose not to study computing: they think it is boring and they do not think they would perform well at it.[21] From the outside, working with technology can seem unexciting, but if one is actually making things with it, technology can be creative and empowering. Unfortunately, because they lack access to mentoring, clubs, courses, etc. many young women have not had the opportunity to see for themselves the opportunities of technology before they enter a beginning design program. Women who are exposed to technology in K-12 education are three times much more likely to participate in STEM majors in college.[22] The second reason, concern about performance, may be due, at least in part, to what is known as 'stereotype threat,' which is when an individual fears that they will confirm a stereotype about a group to which they belong. This has been shown to affect performance and to impact decisions. In this manner, negative stereotypes about women's performance in math and science are thought to be a factor in the inequality found in computing fields.[23] A further reason reported is that women choose not to study technology because they believe technology to be insular and antisocial. With respect to computing, they do not feel that a job in this field entails working with other people or making things which create social good.[24] Another aspect of this is the male-centered gamer culture of today emerged out of early personal computing, which can appear inaccessible to women 'outsiders.'[25] Simply put, when it comes to technology, many women today feel that they do not belong, and because of this, they do not *want* to belong.

Research has shown that women perform well in STEM-related subjects and have the grades and test scores to join in these majors.[26] Furthermore, history is filled with great pioneers of computing such as Ada Lovelace, Joan Clark, and Margaret Hamilton who clearly demonstrate women's capabilities in the field. The ability and potential of women in technology are not in question. The problems discouraging women from participating in technology are cultural and institutional. Education, which has traditionally held the power to shape culture and produce equality, is part of the solution.

Why does it matter?

The gender gap in technology is harmful not only to women, but to everyone. Too often, women are relegated to being users or consumers of technology, rather than its creators. Today, in architecture, being left behind in technology can mean being left out of the design process.[27] A common argument for diversity in design is that inclusiveness invites more experience and perspectives. While true, the importance of diversity goes further than this. When women are underrepresented, there is a risk of their needs being overlooked as design decisions are based upon the experience and opinions of only men. In the past, this has resulted in costly problems such as voice-recognition systems that do not recognize women's voices because they were calibrated for male voices.[28] Worse still, early airbags, designed for adult men, resulted in the deaths of women and children who were not considered as end-users.[29] The development of technology is too important to exclude half of the population, particularly as technology trends like automation threaten more of women's jobs than men.[30] [31] The risks of being excluded are not only lost job opportunities, but declining societal influence. The Global Fund for Women argues that without full participation in the global technology revolution, women's human rights could be violated.[32] The stakes for democratizing access are high. Digital design education is one site of potential inequality which impacts everything from why, how, and what students are taught and has far reaching implications for the discipline and beginning design education. Within the building profession, design technology is an emerging locus of architectural power: those who control the process of design through technology control architectural practice.

Methods

The following are premised on the assumption that further research will define and scope the specifics of technological inequality in architecture and architectural education: how, what, and why. The methods presented here are built upon the supposition that these inequalities are human and not technological constructs and therefore they can be reconfigured through human intervention in technological production, distribution, and education. The methods presented here will focus explicitly upon educational methods as the authors have agency and experience in this realm.

Method 1: Democratizing Access

Democratizing access is the core principle underlying the pedagogy of technology in beginning design at Iowa State University – the method behind the methods in the following sections. Simply put, democratizing access to technology means increasing accessibility: ensuring that there is equal representation among those who use technology and reducing barriers to access, such as cost and education.[33] When the authors develop their courses and curricular policies, they consider whether these actions work in favor of democratizing access.

Method 2: Increasing Digital Literacy

One of the first steps towards democratizing access is to ensure that all Iowa State architecture students – of all genders and backgrounds – possess digital literacy early in their education. To be clear, this is not the same as *computer* literacy, the outdated notion that students must know basic skills such as how to turn on a computer or how to type. It is also not the same as merely knowing how to use a set of software programs – Adobe Suite, AutoCAD, and the like (although our students also learn this). In the curriculum, digital literacy is the critical understanding of how these tools work and work together.

Courses establish the basic principles of computing such as how drawings and models are represented as data and symbol systems and computing 'powers' like dependencies and automation. These are critical ideas for working productively and creatively with digital media which are not intuitive nor apparent from the superficial characteristics of tools and so are often not discovered by 'digital natives.' Furthermore, the authors teach good technology habits: 'soft skills' for working efficiently and effectively.[34] While many courses focus on learning how to use technology, the philosophy at Iowa State is that this is a low bar and not enough, particularly when equality is a concern. Instead, using technology *well* is the objective and it is important for everyone, not only important for some students.

Teaching digital literacy is necessary because students arrive with different levels of exposure to and comfort towards computing and other technologies. In architectural education, these inequalities can manifest as unequal learning and engagement when students are told to learn or use, for example, a new piece of software. Furthermore, as mentioned earlier, stereotypes about women in math and science can affect their level of engagement. Ensuring that all students are exposed to technology can help. Establishing a common introduction for all of our students, particularly one that approaches technology differently than even the experienced students expect, helps to correct some of the inherited biases that students might have about themselves and about each other.

At the same time, the introductory course uses a combination of online tutorials, peer learning, and peer programming to create a more social environment where students can learn digital and computational design. Online tutorials help students to learn at their own pace instead of in a lab where they might be embarrassed about stopping class to ask a question or having other students look over their shoulders. The tutorials help students to self-remediate and mitigate some of the stratification of higher aptitude and novice students. Students work on small projects in peer teams. These are small groups -- usually only two or three students -- who self-select. The advantage of peer teams is that they tend to align with gender; studies show that women often prefer to work together and when they work with other women, they are often less self-conscious about asking questions and asserting technical knowledge.[35] In their teams, students complete their assignments using peer programming, which is a practice where one student uses the software or writes code and the other student observes and discusses. This helps students to focus on smaller parts of a complex task (i.e. learning technology while learning design) and enables them to externalize their thought process with technology. Studies have shown that peer learning and peer programming help reduce the gender gap in student participation and achievement in STEM.[36]

Fig. 2 Flipped classroom at Iowa State University. Photo by authors.

The intention of teaching digital literacy is to give all students a common set of skills and outlooks to serve as a foundation for further learning. The goal of this pedagogy is not to necessitate that all students learn the same requirements and design the same way, but rather to help ensure that students' preconceptions about their abilities and interests do not interfere with their potential for creating and creating with technology. It is this kind of equality the authors' pedagogy pursues. Digital literacy, like 'book' literacy, is not a goal in and of itself. It is the key to learning from and participating within a *literate culture*.

Method 3: Computational Foundations / Computational Integration

Another form of democratizing access is to ensure that computation is introduced to students early and integrated throughout the curriculum. In contrast to computerization (i.e. using the computer to perform tasks, such as drafting; the majority of computing courses teach computerization), computation involves the authorship of instructions for the computer to perform. This is the basis of parametric design, generative scripting, and other developing technologies. In recent years, there has been growing appreciation for the importance of computation in architecture, both in practice and academia.[37]

Fig. 3 Design-build in beginning design studio. Photo by authors.

Today, new technologies, created by architects are the cutting-edge of design and widely seen as its future. Computational knowledge and skills are an integral part of this practice. However, computation continues to be seen as an esoteric and advanced subject, suitable only for electives and graduate study. Moreover, it is often isolated unto itself, as reflected in curricula which tend to accommodate technologies as electives with limited enrollments, a pedagogy which can be non-inclusive and non-empowering. Because computation courses are specialized and involve programming and programming-like activities, the representation of women in them is often low – even lower than in other digital technology courses such as computer modeling, animation, and digital fabrication. This is due to many of the same reasons why there are so few women in Computer Science: gender bias, concerns about personal abilities, and a perceived lack of social value.[38]

The authors believe that teaching computation to all beginning design students is an important step towards improving gender equality. One year after adding computational content to the required foundations course, enrollment of women in elective digital technology seminars improved by 15%. At the time of this writing, Iowa State University is also seeking ways to integrate computation in other required seminars and studios, to show how these methods apply to interests beyond a single required course. An example of this is how computation and digital fabrication are integrated into a required design-build project in the second-year studio. All beginning design students in the program, regardless of background, now experience writing code, operating tools, and using digital fabrication equipment and experience its connection to construction. Introducing computation to the curriculum in this way communicates its importance and makes it a part of the shared culture of the students. Normalizing computation, adding it to students' design vocabulary, and demonstrating its relevance to social and environmental concerns are also ways to increase women's participation.

Method 4: Computation + Construction

Harvey Mudd University increased their enrollment of women in Computer Science by offering all female students research opportunities after their first year in college.[39] This had the effect of helping connect students with significant issues within the field and contributing to projects with meaningful outcomes. Providing research opportunities is one way to help students appreciate the relevance of what they are studying and encourage them to enter into the field. ISU aims to repeat the successes of Harvey Mudd. Beginning by creating an institutional and conceptual space for this work: the ISU Computation + Construction Lab (CCL) which was co-founded by the authors and creates from the existing framework of design-build and digital fabrication a new framework of computation and construction. By linking computation to construction this pedagogic shift harnesses advances in computation as tools for improving construction (robotics, CNC) rather than as tools of representation (renderings, models).

At the CCL, the authors attempt to bridge the gender gap in technology by actively recruiting female students to undergraduate and graduate research positions within the Lab and by providing projects with tangible outcomes that engage the intersection of computing, building, and outreach. As a conscious attempt to normalize technology in the program, the authors select their research assistants on the basis of their studio performance and work ethic, rather than their ability or interest in technology.

At the time of this writing, 65% of past and present research assistants are women (49% of CCL students, overall, are women).[40] Few former assistants have graduated, so the impact of this policy upon their careers is unknown, but within the school, students tell the authors that the visibility of women in the CCL has encouraged them to pursue more technology in their studio work and to seek out their own opportunities for research with the Lab. In the coming years, this is something to be monitored.

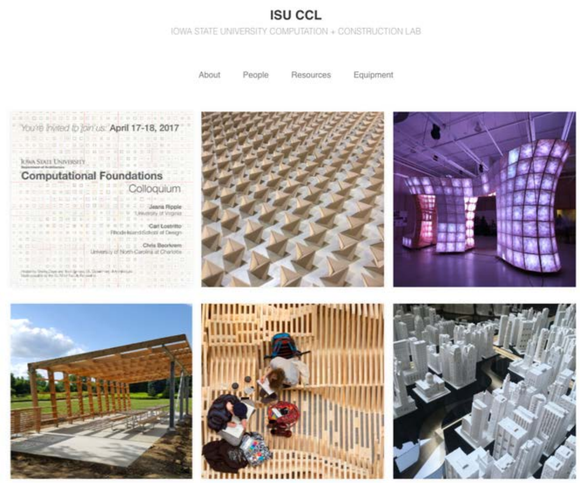

Fig. 4 ISU Computation + Construction Lab Website. www.ccl.design.iastate.edu

Method 5: Dissemination & Critique

To receive peer feedback on the success of these pedagogic shifts the authors are hosting a *Computational Foundations Colloquium* in Spring 2017 as a means for exchanging information and establishing terms of evaluation for what constitutes a rigorous computational foundation curriculum in architecture. One of the topics of this colloquium will be the issue of gender equity in technology and increasing the participation and agency of women.

Conclusion

While technology has rapidly become more accessible to more people, its benefits are not always evenly shared. Despite appearances, access to advanced design technologies such as computational design and digital fabrication in architectural education are not as equal or open as it may seem. Latent inequalities exist which limit participation with technology and threaten an egalitarian pedagogy that empowers all students with the skills and thinking needed to participate in a globalizing economy. This paper searches for methods to define these inequalities, with an emphasis on gender inequality, and proposes ways to democratize access to new technologies in beginning design so that the technology in architecture becomes more diverse and the gender divide is lessened.

An agenda for 'unplugging' inequality begins here. First, architects must start by collecting data on participation in technology – relevant and nuanced data. Next, methodologies for evaluating this data are needed. Last, architecture educators must prioritize technological equity and establish methods for fostering it in schools. In all of these instances, the field may look to the efforts of other disciplines and professions, such as STEM.

The promise of technology as a medium is that it can allow for an individual to be empowered in ways that are not pre-ordained by an institution – the state, the university, the discipline – and as such creates space for a multiplicity of voices to resonate within the architectural profession. Technology can help produce equality, but only if access and participation in technology are equal. At the moment, technology is re-entrenching existing hierarchies, but this can be corrected. Through awareness and conscious effort, human constructs can be undone and retooled to produce greater equality in education and, consequently, the built environment.

Notes

[1] "The future is already here. It's just not evenly distributed yet" — this quote is often attributed to Gibson, though no one seems to be able to pin down when or if he actually said it. http://www.nytimes.com/2012/01/15/books/review/distrust-that-particular-flavor-by-william-gibson-book-review.html Accessed January 2017.

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