An Analysis of the Impact of Apple's Proprietary Electronics Design Practices on Electronics Education

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By

Zak Belkhayat

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISOR

Benjamin J. Laugelli, Assistant Professor, Department of Engineering and Society

Introduction

Electronics education is becoming increasingly unable to capture the complexity of modern technologies, leading students to feel unprepared for the industry (Hughes, 2021). Inherently, the electronics industry is a rapidly growing and changing landscape, as espoused by notable figures such as Intel's co-founder Gordon Moore in his now-infamous "law" that "the number of transistors on an integrated circuit will double every two years with minimal rise in cost" (Moore's Law, n.d.). This pace of innovation also means that companies must constantly develop newer and more sophisticated technologies to match their competition in the field. This has led Apple to design proprietary components instead of adapting existing technologies, as opposed to the early days, where the original Apple I was based on a $20 microcontroller that Steve Wozniak bought off the shelf from an electronics store (Brashares, 2001, pp. 15–19). Apple now has a storied history of battling to prevent its customers from doing similar with its products (despite having recently walked back this stance). This battle has been against the Right to Repair movement. The Electronic Frontier Foundation (EFF) views the right to repair as a step toward allowing "security researchers, consumer protection groups, and other device owners to be able to understand, control, and improve upon the technology they rely upon every day" (Klosowski, 2023).

Currently, researchers and educators are the main actors working on improving education in many fields by taking advantage of digital technologies (Ali, 2019). In the field of electronics specifically, however, few scholarly resources can be found on the role modern devices can or cannot play as case studies for students. Without examining the role modern (and mostly proprietary) technologies play in electronics education, researchers are not exploring how proprietary design practices (like Apple's) are influencing its current state. In analyzing students'

gaps in confidence mentioned previously in relation to the evolution of consumer devices –
namely Apple's widely popular Mac computers and the company's struggle with the Right to
Repair movement – the future of education in the field can be fully explored.

Using the case of Apple and its Mac computers and their many repair restrictions, I will
argue that according to care ethics, Apple is failing to create and maintain the relationships
required to continue improving electronics education and allow for further innovation in the
field. I will outline the relationships affected by current design practices in electronics which
according to care ethics, must be supported to best serve the interests and the rights of students
and educators. In order to examine these relationships, I will analyze current educational
practices and the research on their improvement, as well as research into the justification for
expanding Right to Repair protections in the face of intellectual property law, especially in
regard to Apple.

Literature Review

As mentioned previously, little research can be found specifically on electronics
education and modern digital technologies from reliable scholarly sources. However, there are
two adjacent fields of research which can be examined to synthesize evidence in support of the
claim that Apple can strengthen its relationships with academia to improve educational outcomes
and preparedness. One field is research into the use of electronics and digital technologies for
enhancing general education. The other is research into the effects of right-to-repair legislation
with a general regard to consumer electronics. To this end, one work of research in each of these

concerns will be examined, in addition to a work focused specifically on Apple's role in the right-to-repair movement and its impacts.

With respect to electronics in general education, the work of Wahab Ali in a study titled "The Efficacy of Evolving Technology in Conceptualizing Pedagogy and Practice in Higher Education" explores the justification for educators in taking advantage of "technology and technological gadgets" with the end goal of "[creating] a digitally vibrant society" (Ali, 2019, p. 81). Ali's argument signifies the importance of examining how the proprietary technology in consumer electronics will affect educational outcomes. If these devices will be increasingly incorporated into education, then it stands to reason that their degree of accessibility can have a large impact in a classroom setting.

The work of Leah Chan Grinvald and Ofer Tur-Sinai, published in the Fordham Law Review and titled "Intellectual Property Law and the Right to Repair," explores the justification for enshrining a right-to-repair in the law, and how this concept relates to intellectual property laws. As stated in the abstract of the article, "requiring manufacturers to release repair manuals could implicate a whole host of intellectual property laws" (Grinvald & Tur-Sinai, 2019, p. 63). This is an oft-used argument by tech firms in explaining why they hesitate to support independent repair. However, Grinvald and Tur-Sinai argue that the right to repair can be upheld while also protecting intellectual property. This perspective is important for realizing the importance of and the roadblocks to encouraging tech firms to provide more open support, and why right to repair legislation can impact technological innovation and understanding for students and educators.

Jumana Labib's work is focused specifically on Apple's history in the world of repair, and has a slight bias against their practices. Nevertheless, Labib's argument is that the modern state

of repair has contributed to an "oligopolistic" market, essentially claiming that this loss of repair knowledge has led to stifled innovation from less advantaged players in the industry (Labib, 2023, p. 7). In this sense, Labib's work can contribute greatly to the question of how Apple's role in repair specifically has potentially impacted the landscape of innovation and education.

This paper's aim is to synthesize these works to provide evidence that the design of Apple's modern Mac computers is affecting educational outcomes for the students learning to work in the same industry, and wider innovation in the field. By examining the effect of electronics on general education, the justification for making the repair and manipulation of electronics more accessible, and the role Apple has had in the area of repair, the link can be made between Apple's design choices and the educational outcomes of electrical and computer engineering students, as well as continued innovation. Therefore, this paper can prove a connection between Apple's design practices and the state of electronics education and innovation, and secondarily fill a gap in the pre-existing research on modern technology's effects on education with regards to specifically technology-focused disciplines.

The Care Ethics Framework

Care ethics is invaluable in examining the case of Apple and its Mac computer products and the impact their design has had on electronics education. While the concept of care ethics is abstract like many ethical frameworks, and sometimes hard to define, the key aspect of the framework is relationships (Poel & Royakkers, 2011, p. 102). Care ethics posits that to be moral and ethical, one must develop relationships in accordance with the moral obligation to support and understand others (Poel & Royakkers, 2011, p. 102). Other ethical frameworks are more

focused on the individual, neglecting the relationships that are inherent to ethical engineering practices (Poel & Royakkers, 2011, p. 104). This means other ethical frameworks can cause a kind of narrow-minded focus on engineering design. An application of care ethics in the form of the "Social Ethics of Engineering" indicates that key "norms of engagement" are democratic information flow, cooperativeness, and creativity (Poel & Royakkers, 2011, p. 104). The case can be made that Apple is failing to maintain these norms in its relationships through their design decisions. Poor upkeep of these relationships can result in negative consequences for the firm, as evidenced by its struggle with legislation on the Right to Repair. Care ethics and these established norms of the Social Ethics of Engineering will therefore be used to examine the nature of Apple's relationships with specific groups, and how those relationships are affecting the average consumer and education.

Analysis

Educators, Students, and Technology

Presently, numerous digital technologies are already being widely integrated into all forms of education, and researchers are finding that it is not only an inevitable intersection, but that it has potential to affect educational outcomes greatly. Dr. Wahab Ali, a professor of education at the University of Fiji, carried out a study designed "to examine the influence of evolving technology in conceptualizing pedagogy and practice in higher education" (Ali, 2019, p. 82), to support the claim that this evolving technology is affecting the success of educators. Ali found that among 67 teaching staff surveyed, 92% felt that educators need more confidence in what Ali calls Information Communication and Technology (ICT) (Ali, 2019, p. 86). ICT in this case includes online learning companion tools, content delivery sites like YouTube, and online collaboration apps. Despite this apparent lack of confidence, 93% of the teaching staff

surveyed felt that "Students need basic ICT knowledge" (Ali, 2019, p. 86). These findings match up with sentiments from the previously cited survey by ZDNet, which showed most leaders in the information technology (IT) field believe younger generations will solve a "digital skills shortage," while over half of young people surveyed said they wanted more info from educators on technology careers (Hughes, 2021). Looking at these sources in tandem, educators and students alike believe technology is increasingly important in education, including in IT, which is closely related to the electronics industry. Additionally, according to UNICEF, teachers' and trainers' lack of capacity to teach digital literacy is a key barrier to improving it, among: "lack of ICT infrastructure; low connectivity (especially for remote areas); and a lack of understanding from decision-makers" (*Digital Literacy for Children, n.d.*). These barriers are all potentially affected by the actions of firms concerned with ICT and electronics, since they have the ability to distribute their infrastructure, optimize access, and work with legislators (decision-makers) on regulating technology.

These findings establish that technology is becoming an integral part of education and the futures of young people, and the connection can be drawn to several aspects of young people's lives. Despite this, educators admittedly lack confidence in teaching ICT. This draws the relationship between educators and students, which is a mutual desire to improve ICT skills. In this way, educators feel a moral responsibility to teach students, but they require external assistance. This is where Apple, under care ethics, has an obligation to maintain the norm of cooperativeness and democratic information flow. As shown by ZDNet's survey, IT leaders (in this case executives at Apple) are admittedly relying on young people to improve their skills crisis, and as such are morally obligated under care ethics to be involved with this issue in teaching confidence if they wish to maintain this relationship. This lays the groundwork for why

Apple should be concerned with the issue at hand in the first place, establishing justification for their care in this regard.

The Significance of Right to Repair

Part of the claim of this paper is predicated on the idea that a lack of right to repair is contributing to the previously mentioned barriers to digital literacy. The right to repair has a storied history, and it has evolved and changed in many ways since the first consumer electronics products were introduced. For a very long time, large electronics corporations have fought against giving consumers a right to repair their devices independently. As far back as 1956, when IBM was found in violation of anti-trust laws and agreed to make it easier for consumers to repair their devices, there has been a growing culture of concern over the freedom to tinker with one's own devices (Grinvald & Tur-Sinai, 2019, p. 73). Leah Chan Grinvald (an Associate Dean at Suffolk University Law School) and Ofer Tur-Sinai (Associate Professor of Law at Ono Academic College) explain some of this history in their Fordham Law Review article on "Intellectual Property Law and the Right to Repair." Grinvald and Tur-Sinai suggest that the recent growth in concern over the right to repair has come in part from the fact that most physical consumer products today have some form of electronic chip or embedded technology (Grinvald & Tur-Sinai, 2019, p. 73). Thus, it stands to reason that difficulties in repairing or understanding these products can contribute to a general reduction in competencies. The authors of this article also address Apple's role in a court case against an independent repair shop. On the grounds of trademark infringement, Apple claimed a repair shop was using counterfeit screens in its repairs, but this was determined false since these screens were simply refurbished genuine components (Grinvald & Tur-Sinai, 2019, p. 74-75). Apple was intent on maintaining their brand by protecting their IP and ensuring repairs only contain genuine parts.

This exposes the alternative perspective on repair and one of the core foundations of this source; that companies should be able to restrict certain repair or tinkering processes in the name of upholding their intellectual property rights, or in certain cases to promote safety. Along with proposing model legislation to encourage open repair, Grinvald and Tur-Sinai address the issues pushing improved legislation forward, ergo the issues preventing open repair. This requires a justification for why the right to repair should be upheld even in the face intellectual property concerns. Several large manufacturers have been making notable attempts to stall or end legislation that would open repair, including companies such as Dyson, Wahl, and LG (Grinvald & Tur-Sinai, 2019, p. 80). Grinvald and Tur-Sinai argue that despite the actions and concerns of these corporations, the right to repair has a valid place even among established intellectual property rights, due to several factors including general consumer rights and environmental concerns (Grinvald & Tur-Sinai, 2019, p. 84). They state that despite consumer interests in repair being external to the nature of intellectual property rights, this does not make it irrelevant (Grinvald & Tur-Sinai, 2019, p. 84). Using a utilitarian perspective, the authors also argue that given the base moral assumption of "[maximizing] net social welfare," the internal players in intellectual property concerns should also accept the benefits of free repair (Grinvald & Tur-Sinai, 2019, p. 85). This perspective reveals the moral obligation Apple has in relationships with legislators to establish mutually beneficial legislation based on the norm of democratic information flow and cooperativeness, when examined using the framework of care ethics. In addition to relationships with legislators, Grinvald and Tur-Sinai set out a case for the relationships between companies and their customers. They argue that under a "traditional view of the IP Clause," the right to repair also "[enhances] consumers' ability to benefit from the innovative products brought about by technological progress" (Grinvald & Tur-Sinai, 2019, p.

87). To add to the dynamics of this relationship, Grinvald and Tur-Sinai explain that user innovation is one of the key drivers of technological progress, especially in the modern world where high technology is accessible to so many. In this vein, they argue that social progress is then brought about by this user innovation (Grinvald & Tur-Sinai, 2019, p. 90). To strengthen this point, they discuss the story of the first controlled flight by the Wright brothers, which in part came about from Wilbur tinkering with a "rectangular bicycle inner-tube box," a component of a bicycle produced by a manufacturing firm, not by the brothers themselves (Grinvald & Tur-Sinai, 2019, p. 90). These perspectives reinforce the moral obligation of care in Apple's consumer relationships by exposing the potential effects of repair legislation on general social progress through the actions of users.

The norm being neglected here is that of creativity. Users are unable to use the products created by Apple to generate new products or ideas using their technology as a basis. This draws back to the case of its storied line of Mac computers. Modern users are unable to follow cofounder Steve Wozniak's footsteps in adapting off-the-shelf technology using Apple's Macs. Apple has therefore deteriorated in its norms of creativity and democratic information flow compared to its origins. Grinvald and Tur-Sinai argue that this is exactly the kind of thing that can have a negative impact on innovation, where companies are stifling a new wave of inventors. Thus, the company-consumer relationship's duty of care is seen as one of the most important relationships for Apple if they aim to continue social and technological progress.

The Case of Apple and Mac Computers

As mentioned, Apple and the evolution of its Mac line of computers is a strong case to examine when inspecting the moral duties of tech firms in their relationships with certain groups. Having established the importance of these relationships and the impact they can have on

progress and education, the case of Apple can be used to examine the concrete actions and design principles that affect these relationships. Jumana Labib, an undergraduate who was published in the global undergraduate awards of 2023, wrote of Apple's role in the right to repair and the impacts it has had on society at large. Labib, quoting Aaron Perzanowski's book "The Right to Repair" writes that Apple "has an obsession with controlling the user experience, because it has proven to – quite literally – pay off" (Labib, 2023, p. 12). In this way, Labib claims Apple is stifling repair in an effort to lock users into its ecosystem and continue spending money as opposed to repairing their devices independently (Labib, 2023, p. 13). Labib also addresses Apple's previously mentioned history in regard to its first computer products. The Apple I and II computers "were shipped with technical descriptions of the systems' processors and circuit designs" (Labib, 2023, p. 13). This is as opposed to today where Apple has continually attempted to remove access to its repair materials and intellectual property. As mentioned by Labib, independent repair company iFixit, which has a plethora of manuals and guides available for their users to repair devices and rates the repairability of products, rated Apple's laptops at a D- in terms of repairability (Labib, 2023, p. 14). Despite slowly agreeing to support right to repair legislation like in their recent support of President Biden's push for right-to-repair(Shalal et al., 2023) and creating programs meant to widen repair access like their Independent Repair Provider program, Apple still tries to keep control over repair processes by requiring random auditing and inspections to ensure no (vaguely-defined) "counterfeit" parts are used (Labib, 2023, p. 15). In the case of its MacBook line, a 2018 CBC report found that an independent repair shop owner could offer repairs on the computers at a fraction of the cost of Apple's own repair outlets (CBC, 2018), showing that Apple's exorbitant fees and lockdown of repairs are costing consumers greatly. The Verge also found that despite Apple's seeming approval of independent repair, it is

still using software checks and design principles which restrict repair to costly, Apple-approved methods (Stone, 2023).

This collection of incidents shows that Apple specifically is failing in the moral duties set forth by care ethics. All three norms mentioned in the application of care ethics have been negatively impacted by Apple's actions. Democratic information flow has been all but removed because the technical details and repair guides for its Mac computers are nearly impossible to find for users. Cooperativeness is poor, since they continuously stifle independent repair shops' attempts to fix its computers under the guise of safety and IP concerns. Creativity is at best discouraged, given the combination of violations of care resulting in difficulty for users wanting to innovate on Apple's technology. They are violating their relationships under an application of care ethics, which can affect digital literacy and stifle societal progress and innovation. The principles of care ethics state that Apple could be engaging in more mutually beneficial actions that include diversifying repair access, and their decisions over the course of the company's existence have instead resulted in a failing in its relationships.

Conclusion

Current research is focused on several aspects of this paper's main claim independently, but there is a lack of resources that synthesize these aspects to show that Apple has a moral obligation to design in such a way that they account for education and digital literacy, especially in the tech field. Apple can diversify access to their designs and repair methods to preserve technological innovation and societal progress on top of ensuring that the new generation of engineers and workers are equipped to deal with rapid technological change. This is on the basis that not doing so could lead to negative consequences in its future growth as well as in the future of a wide range of rising young professionals. The essential perspective to be derived from this

work is that there is a clear link between Apple, tech innovation, and educational outcomes in electronics, as the more complex and obfuscated its devices become, the less its consumers will be able to learn and improve upon.

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