Failing to Succeed: An Investigation into Sociological Factors that Caused Innovations in Computer Science to Fail

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring 2024

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

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Introduction

Failure is pervasive within the field of Computer Science and Engineering (CSE), with even Silicon Valley boasting the unofficial motto of "fail fast, fail often" (Draper, 2017). Failed innovations are those which, regardless of their technical excellence, fail to gather the momentum necessary for widespread adoption within society and consequently fade away. A few prime examples of this can be seen with early versions of Artificial Intelligence (AI), Virtual Reality (VR), and keyboards that challenge the typical QWERTY format. The issue of failed innovations is problematic, as new inventions can advance society by creating new jobs, growing the economy, and making old processes more efficient. Imagine how productive our society could be if we had achieved modern day AI and VR twenty years earlier. Innovation failures are generally attributed to technical issues such as a lack of computing power and data for early AI (Raja, 2023) or significant technical design flaws with early VR headsets, specifically the Nintendo Virtual Boy (Boyer, 2009). However, this simplification causes a large category of potential reasons for failure to be ignored, namely their faulty sociological components.

While creating these new innovations is important to the advancement of society, manufacturing them requires an understanding of the components necessary for success. This allows new inventions to be designed in an optimal manner. This understanding is the goal of the field of innovation studies (Fagerberg et. al, 2013). While a majority of innovation studies focus their attention solely on successful innovations and their components, doing this ignores a large amount of potentially useful information such as identifying factors that caused innovations to fail (Benskin et al., 2021). This paper will investigate case studies and perform innovation studies of failed innovations within the field of CSE with the goal of identifying actors that contributed to each innovation's failure.

History of Innovation Studies

Despite the fact that innovation is vital to the improvement of society, the field of innovation studies is rather new. The field was established in the 1950s due to the end of the Second World War, when the United States' defense industry realized that they needed a better understanding of innovation and its components (Fagerberg et. al, 2013). Since its establishment, the field has grown from a small circle of academics to thousands of researchers that have had major impacts on both innovation studies as well as the production of new inventions. The main focus of these researchers has been gaining trustworthy and systemic information on how to best influence innovation in order to produce the optimal impact on society (Martin, 2012). Although these researchers have been collecting this information for more than sixty years, a majority of the research performed has been examining components that have made innovations successful (Benskin et al., 2021). Because of this, there is a significant research gap regarding the factors that lead to innovative failure. By gaining a deeper understanding of potential patterns that failed innovations share, inventors would be able to better avoid potential pit-falls, allowing society to gain the optimal output from a larger number of inventions (Benskin et al., 2021).

Recently, a small number of researchers have performed case studies on innovations that were introduced to society but failed to gain widespread adoption, classifying these as failed innovations (Benskin et al. 2021). One of the recent studies examines the failure of Google Glass. Google launched this product in 2014, with the hopes of putting smartphone capabilities into a pair of wearable glasses (Weidner, 2023). Ultimately, the innovation study determined that this product failed for a multitude of reasons. These reasons can be further classified into either "no market demand" or "poor product performance" (Benskin et al., 2021). Google Glass struggled with market demand due to the $1500 cost of their product and their poor choice of target audience, specifically the social group of fashion designers. Furthermore, Google Glass encountered issues with poor product performance, as their product had a poor battery life and had significantly fewer third party applications and slower processors than their smartphone competitors (Weidner, 2023). After finalizing the results of twenty different innovation studies, including the one on Google Glass, Benskin identified five main components of innovative failure: no market demand, poor product performance, insufficient funding, regulatory restrictions limiting the product, and inability to secure market position such as failure to receive intellectual property protection (Benskin et al., 2021).

While the conclusion of these innovation studies are logical, all of these categories focus on technical or economical issues rather than sociological ones. This has been a consistent downside in innovation studies, which are often performed by economists seeking to make inventions successful (Bijker et al., 1987). This paper hopes to counteract the typical drawbacks of innovation studies by not only examining case studies of failed innovations, but also prioritizing the analysis of potential sociological factors which caused these inventions to fail.

Theoretical Frameworks

Before proceeding to the case studies on failed innovations within CSE, this paper utilizes STS specific theories throughout the following analysis. The first STS concept this paper discusses is the notion of radical and conservative innovations. The idea behind this is that every innovation can be categorized into either a radical innovation or a conservative innovation. In general, radical innovations are typically those which instantiate a new technological system, while conservative innovations are those which expand and grow upon existing systems (Hughes, 1987, p. 51). While this definition provides a rather black and white definition of radical and conservative innovations, I argue that inventions may not be able to be so neatly divided. Throughout the remainder of this paper, the conflict between conservative and radical innovations will be explored as one of many potential reasons that previous inventions have resulted in failure.

The second STS concept this paper discusses is the phenomenon of technological lock-in. Technological lock-in is the event where the established dominance of a certain technology makes it difficult for other technologies to gain traction, despite the fact that they may be technically superior (Shogren, 2013, p. 123). This concept shares some similarities with the conflict between radical and conservative innovations, as oftentimes existing conservative innovations are the established dominant technology, which causes difficulties for radical innovations to gain traction. While there is some overlap, this is an important theory to discuss as it has been the cause of numerous inventions failing to gain widespread adoption.

Methods

In order to collect the sources used throughout this paper, a literature review of innovation studies and failed innovations within CSE was performed. I began by searching through a combination of the UVA Library's online search tool, Virgo, and Google Scholar using a predefined list of keywords that were related to my topic. The list included keywords such as innovation studies, failed inventions, artificial intelligence, early artificial intelligence failures, virtual reality, early virtual reality failures, technological lock-in, radical vs. conservative innovation conflicts, setting expectations, and many more. I then sifted through articles identifying those which were relevant to subsections of my paper. After locating three sources for each section, I then read through a majority of each article and was able to compile useful information from each article as well as locate new sources that helped further support my argument. Once all evidence was gathered, I used a combination of personal outlines, rough drafts, and smaller assignments to form my analysis of the information for the final draft.

Case Studies of Failed Computer Science Technologies

Innovation failure is common through all disciplines; however it is especially relevant in the field of CSE. A prime example of this is that Silicon Valley, the technology capital of the world, has earned a motto which encourages developers to fail and learn from their mistakes in order to ultimately achieve success (Draper, 2017). Despite failure being ubiquitous, in order to perform a thorough examination of failed innovations, it is important to first define what makes an innovation a failure. Johnson suggests that innovative success is not dependent on an invention's excellency, but rather whether an invention gains widespread adoption amongst social groups as a means of achieving their goals (Johnson, n.d.). A few examples of innovations within CSE which have failed to achieve widespread adoption are early forms of AI in the 1970s, VR headsets, and challengers to the QWERTY keyboard. Each of these case studies provides a unique perspective into components that cause different categories of innovations to fail. In the case of early AI, it was originally regarded as a failure and is now one of the hottest topics in computer science. VR is intriguing as it has encountered numerous issues which keeps it from gaining widespread acceptance, despite the significant increase in computing power. Lastly, challengers to the QWERTY keyboard impart a fascinating phenomenon where inventions which have been proven to be scientifically more efficient fail to gain widespread adoption.

Early Artificial Intelligence

A prime example of a failed computing innovation can be seen in early AI. While algorithms, data storage, and computing power have changed greatly over the duration of AI's existence, a majority of AI models operate in a similar manner. Most models are trained on an abundance of data with the goal of optimizing a mathematical formula, which will later be used to predict new data or categorize this data into individual groups (Mueller, 2021). While there is presently lots of hype and new technologies being produced within AI, this is not the first time that the computer science field has witnessed this trend. Early versions of AI can be traced back to the 1950s. From the 1950-1970s, scientists attempted to create an artificial neuron, the first chatbot, and the first industrial robot (Raja, 2023). During this time, there was great excitement surrounding the field; however in the mid-1970s this hype came crashing back down, which led to the onset of the first AI winter. There have been two major AI winters throughout the history of AI. These winters are generally regarded as a period in time where research and funding decreases significantly in the field, due to unrealistic expectations not being met (Muthukrishnan et al., 2020). During the first AI winter, many well-renowned scientists voiced their doubts about the capabilities to train larger models due to the lack of data available to train the model, as well as the insufficient degree of computing power (Raja, 2023).

Although it is certainly true that the current state of technology was unable to support new theories for improving AI, this limited analysis ignores other potentially important contributors to the first AI winter. The first non-technical factor leading to the failure of early AI has to do with the concept of setting expectations. In the past, AI has set many expectations unbelievably high only to be later challenged to meet them. When this occurs, investors often become skeptical and pull funding for AI, making the problem of meeting these expectations even more improbable (Muthukrishnan et al., 2020). Additionally, inventors setting egregiously high expectations can also be detrimental to their everyday consumers. If initial expectations for technologies are set too high, the hype around the innovation can quickly turn into disillusionment or abandonment of the product (Borup, 2006). This means that innovators need to develop ways of effectively advertising their creations without setting unrealistic or unattainable expectations for that product. Consistently maintaining this balance should be a goal for all innovators. Furthermore, Brown states that, in order to determine whether to trust a current actors' expectations, consumers will often look to the past to see if the actors' previous expectations were met (Brown et al, 2003). This means that setting realistic expectations will not only be beneficial for inventors' current products, but it will also assist them in the future by consistently meeting these expectations and gaining customer trust.

The notion that consumers often look to the past to determine whether to trust a current inventors' expectations by default gives an advantage to conservative inventions. By definition, these conservative inventions are those which improve upon an existing technological system (Hughes, 1987). Thus, established conservative inventions can afford to set higher expectations and drum up more hype for their invention, as they have a consistent track record of success. This is a luxury that many radical inventions can not afford, as setting too high expectations with the lack of prior success can often lead to the demise of the invention much like what occurred with early AI (Muthukrishnan et al., 2020).

While inventors must be cautious when setting expectations for their innovations, there are also a multitude of other factors that could cause an innovation to fail. When considering the case study of early AI, setting expectations is clearly a factor in the failure; however there may have also been other issues. Another factor Hendler identifies comes from the research community disowning technology within the expert systems field (Hendler, 2008). Expert systems was originally included within the field of AI as it relied on information from human experts to construct a list of predefined rules. This is rather different from the traditional view of

AI as it is static and relies on a list of predefined rules; however for early forms of AI this was considered acceptable as it greatly reduced the computing power required (Mueller, 2021). Nearing the beginning of the first AI winter, many AI researchers were beginning to feel the impacts of budget cuts, causing many of them to state that the expert systems were not “real AI”, thus mistakenly exiling one of the field's last remaining well funded projects (Hendler, 2008).

Virtual Reality

Another intriguing innovation within the field of CSE, which has failed to gain widespread adoption is VR. While many think of VR to be a recent invention, the first VR head-mounted device, The Sword of Damocles, was invented in 1968 and flight simulators that used technology similar to VR were invented in the 1920s (Kenwright, 2019). These early versions of VR showed some signs of success but ultimately flamed out due to technical issues and cost. While The Sword of Damocles is regarded as being the first VR headset, it is entirely different from the modern lightweight VR headsets. In order to support the headset’s weight a room was needed such that a mechanical arm extending from the ceiling could support the headset. Furthermore, many users experienced severe simulation sickness from early VR, causing many to be so traumatized to completely abandon it (Heffernan, 2014). These technical issues, which made VR extremely inaccessible, combined with the cost of manufacturing and difficulty to monetize, ultimately led to the failure to gain widespread adoption in early VR.

Recently, there has been another surge of VR technology. Despite now having the technology to design small and easily accessible VR headsets that have smooth graphics to mitigate a majority of simulation sickness, these headsets are still having problems gaining widespread adoption. In 2023, sales of VR headsets dropped by 40% (Vanian, 2023). While cost is still a factor that is withholding this technology from gaining widespread adoption, with the average price for a headset at $500 (Vanian, 2023), there are many other issues that could be contributing factors.

The first non-technical issue, which may be detrimenting the adoption of VR, comes with gray areas surrounding the metaverse. The metaverse is a popular concept within the field of VR in which users interact in a shared 3D space simulated by software. Some advanced metaverses even include their own economies, properties for users to buy, and large scale events attended by players (Sparkes, 2021). At first this concept fostered lots of hype for VR; however recently many gray areas such as how to solve legal matters such as stolen cyber-property, virtual violence and sexual harassment, and online vandalization have diminished this hype and posed new challenges to the adoption of VR (Gandhi, 2018). While these gray legal areas certainly have caused hesitancy with regards to the adoption of VR, a separate issue can be found with the inability to identify and target relevant social groups. In a recent survey only 29% of teens in the United States stated they owned a VR device, with 4% who use it daily, and 52% who were uninterested in owning the device (Tangermann, 2023). This is problematic for VR as the younger generations have typically driven the adoptions of new technology such as computers and smartphones (Tangermann, 2023).

` The final issue that modern day VR faces has to do with the notion of technological lock-in. Despite the fact that many technological issues of the headsets have been fixed and their cost reduced greatly, VR is still having a difficult time gaining adoption due to the popularity of smartphones and tablets. Rotter states that when comparing the 2D images seen on our tablets and smartphones with the 3D images presented by VR, not as much new information is added as our brain does a phenomenal job of inferring depth (Rotter, 2017). He further argues that given this users' have become accustomed to seeing images on a 2D screen, thus reducing the demand for the 3D technology (Rotter, 2017). Furthermore, given the popularity of these 2D screens a significantly larger amount of content such as applications and games have been produced for these devices. This lack of exciting content for VR has been one of the main challenges in the technology gaining widespread popularity (Vanian, 2023). Overall, given the popularity of smartphones and tablets, this has led to users' becoming adjusted to receiving information from a 2D screen as well as significantly more information being available in a 2D manner. Both of these have posed challenging issues to the success of modern day VR, as many new users are hesitant to try the technology due the reasons outlined in this section.

Challengers to QWERTY

Lastly, another innovation within the field of CSE that failed to gain widespread adoption can be seen in keyboards that challenge the dominant QWERTY format. While there have been many alternate formats built, the most popular one, which is now supported by most modern computers, is known as the Dvorak keyboard (Oxer, 2004). Although there have been conflicting results on which has the fastest typing speed from studies where typists were trained to proficiency on both the Dvorak and QWERTY keyboards (Kissell, 2014), one thing for certain is the Dvorak keyboard requires much less hand movement. This is due to the fact that the inventor, August Dvorak, spent many years studying the English language and letter patterns. This allowed him to design a keyboard which allowed roughly 65% of the words in the English language to be typed without your hands leaving the central row, as compared to the QWERTY keyboard which only allows 30% (Oxer, 2004).

Considering the superiority in efficiency of the Dvorak keyboard two pertinent questions arise: Was the QWERTY keyboard designed in an inefficient manner? And if so, why has it not been replaced by a superior format? Addressing the first question, the keyboard keys were purposely arranged inefficiently as a way to slow typists down, as typing too quickly on a typewriter would lead to jammed keys. When these keys jammed, it would cause every following keystroke to print the same letter as the jammed key, which meant that a series of repeated letters would occur and would only be noticed after the typist lifted the typewriter carriage (David, 1985). In an attempt to prevent this, the QWERTY keyboard format was invented with the hopes of slowing typists down and therefore stopping key jamming. The second question is a bit more nuanced and has been the focus of numerous case studies. The main conclusion is that QWERTY has not been replaced due to the phenomenon of technological lock-in.

While technological lock-in is a factor mitigating the success of modern VR, there are also many other sociological, technical, and economical challenges it is facing. However, many innovation studies investigating the Dvorak keyboards solely associate technological lock-in as the reason behind the keyboard's failure to gain widespread adoption. Due to the concept of technological lock-in, whether or not an invention is successful may involve more than just the economic, technical, and social features of an innovation, but may require a deeper analysis to be performed on similar inventions and the relationship between them. This poses a rather similar issue to the concept of the competition between radical and conservative innovations. While the Dvorak keyboard may be considered a conservative invention as it improved upon an existing technology and made it more efficient, it should be considered radical as it dramatically changed the keyboard format with the hopes of stealing market share from the dominant QWERTY keyboard. With this in mind, this is yet another example where conservative innovations dominate their radical counterparts even if the radical innovation is better than or equal to it.

Conclusion

Innovations failing to gain widespread acceptance will always be problematic as some issues cannot be avoided or are impossible to predict. However, by broadening the field of innovation studies to include examining failed inventions as well as considering their sociological components, it may provide valuable insights to inventors. When considering early Artificial Intelligence, in addition to the low funding and insufficient amount of computing power and storage, many other sociological issues can be identified. These include overhyping the product leading to future disillusionment when the product does not meet these high expectations and rashly excluding successful sub-components of the technology. The Virtual Reality case study is intriguing as initially the technology was stifled due to technical and economical issues such as inaccessibility, high cost, and poor graphics leading to simulation sickness. However, as technology has improved VR has faced other challenges such as how to proceed with legal matters in the metaverse, lack of content due to the success of smartphones and tablets, and how to properly advertise the product to its relevant social groups. Lastly, the Dvorak keyboard case study provides insightful information as this technology can be proven to be scientifically more efficient than its widely accepted counterpart, the QWERTY keyboard. However, due to the phenomenon of technological lock-in this has allowed an inefficient technology to remain dominant solely because it obtained widespread adoption first. As future innovation studies identify other components which have contributed to the failure of previous innovations, inventors should be able use this information to bypass common drawbacks and give their new inventions a better chance at reaching widespread adoption.

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