AC 2010-12: ETHICS' ORPHAN: UNINTENDED CONSEQUENCES

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Abstract

This paper explores unintended consequences, those unpredictable repercussions that inevitably result from an action or decision. While ethical problem solving involves examining the ramifications of potential courses of action, unintended consequences is a topic typically not included in a standard ethics course. Specifically, the paper focuses on definitions, types, a case study of the 1915 Eastland disaster, contemporary examples, and classroom suggestions.

Introduction

"Technology," notes Steven VanderLeest "is not neutral. It has an intrinsic bias that is built into it from the original inception of a particular problem, throughout the entire design process, all the way to the implementation, use, and disposal of a product." That bias, he further explains, determines the primary use of the device, although the user certainly can employ the product in "ways the designer did not intend."[1] Because human practitioners do not always follow predetermined usage, unforeseen results emerge.

Unintended consequences are inevitable, due to our inability to project how we will interact with new technology or decisions. Typically, these consequences are negative, "unpleasantly rather than pleasantly surprising," as Edward Tenner suggests,[2] ranging from the trivial and inconvenient (Wii addicts who accidentally throw their remotes through television screens due to sweaty hands) to the potentially life-threatening (the arms race that ensued from the Manhattan Project). Because they are unpredictable, unintended consequences naturally flow from virtually every invention, action, and decision that we make.[3]

This paper examines the phenomenon of unintended consequences, focusing on definitions, types, a case study, contemporary examples, and offers pedagogical suggestions for exploring a topic that is not typical ethics fare. Because engineers design and develop technology, which Tenner defines as "humankind's modification of its biological and physical surroundings,"[2] it is crucial that our students become aware that "things" may take on lives of their own, which may be anathema to their envisioned function.

Definitions

A number of authors call for a broader education in engineering that includes study of the liberal arts, economics, and public policy—three areas that engineering and technology development impinge upon. Technological change results "from the very nature of technology and the priorities and conscious motivations of those who design and implement technology"[4] and is thus part of a political process. To remove engineering from its social, economic, and political contexts and view it as a singularly technical venture also serves to remove the responsibility for the use of these technological creations.

A study of unintended consequences clearly links design, use, and responsibility issues. For the purposes of this paper, we will use Daniel Little's definition of the term as "a result that came about because of deliberate actions and policies that were set in [motion] at an earlier time—so an unintended consequence is the result of deliberate action. But the outcome is not one of the goals to which the plan or action was directed; it is 'unintended.'"[5]

Sociologist Robert K. Merton provided the first major analysis of the concept in 1936 and identified five possible conditions that result in unintended consequences:

1. Ignorance: an inability to predict everything

2. Error: a mistaken analysis of the current situation or past trends contributing to it

3. "Imperious immediacy of interest": focusing on current benefits and ignoring long-term ramifications

4. Basic values: implementing immediate values even if the long-term result may be detrimental

5. Self-defeating prophecy: predicting a consequence becomes a new factor in determining the consequence[6]

While these certainly remain valid reasons, factoring in the computer revolution and systems thinking yields three more, as explained by cognitive psychologist Dietrich Dörner:

1. Complexity: the existence of multiple variables and the interrelations between these, each affecting the system as a whole as well as each other

2. Dynamics: the tendency of systems to act independently, regardless of the wishes of the controller

3. Intransparence: elements of a system that are not visible but affect the performance of the system, introducing an element of uncertainty[7]

Unintended consequences are thus more than a simple yin-yang proposition, as control engineer Mark Spong suggests, where opposites contain the seeds of each other: good and bad outcomes are, in part, inherent in each other.[8] Unintended consequences are not simply "bad" or "unforeseen"; they are unpredictable and hence beyond our control in the design or decision-making phase. They occur only after implementation, and, Dörner suggests, they occur in logical patterns.[7]

Types

Actions, decisions, and technological devices, then, all have unintended consequences, and these vary by field. In medicine, for example, questions arise concerning the long-term, unforeseen effects of cloning, recombinant DNA, stem cell research, and a host of other current topics. In popular culture, social networking sites such as FaceBook and MySpace raise issues of privacy and predation. In economics, the consequences of the federal stimulus package remain to be seen.

In engineering and science, unintended consequences fall into several general categories:

Side effects are "additional, unanticipated effects that occur along with intended effects"[9] and are usually associated with pharmaceuticals: taking too much aspirin may affect the gastrointestinal system. However, technology also has side effects. In examining the effects of video games, we could say that some level of addiction was a probable outcome, but pediatric kidney conditions, caused by the mesmerizing quality of the video screen,[10] are unintentional.

Inadvertent experiments are those actions that "unwittingly allow and sometimes force society to consider the effects of its actions," such the holes in the ozone layer or climate change.[9]

Obsolescence refers to the disappearance of certain occupations or technologies due to new inventions.[11] As is the case with side effects, some of this is certainly predictable: the computer replaced both the typewriter and typewriter repair person. What is unintended is the vast accumulation of electronic waste in third world countries that has devastated the environment of entire regions, such as Guiyu, China.[12]

Reverse effects occur when actions boomerang: "scientific and technological development, after crossing a certain threshold, may exhibit a counterproductivity, producing new problems even as it solves old ones."[9] Ivan Illich, in a 1974 treatise, describes the reverse effects of the transportation sector: "From the moment its machines could put more than a certain horsepower behind any one passenger, this industry has reduced equality among men, restricted their mobility to a system of industrially defined routes and created time scarcity of unprecedented severity."[13]

Revenge effects, a phrase coined by Edward Tenner, are perhaps the most intriguing types of unintended consequences. A revenge effect is "the tendency of the world around us to get even, to twist our cleverness against us."[2] These types of consequences are rather perverse, he continues, and "whenever we try to take advantage of some new technology, we may discover that it induces behavior which appears to cancel out the very reason for using it."[2] For example, at the dawn of the computer revolution, Alvin Toffler and other self-proclaimed prophets of technology predicted that a paperless office would ensue, that the storage capabilities of computers would obviate the need for paper documents. What happened, however, is that the use of paper surged to much higher levels than before computers! "Paper," concludes Tenner, "seemed to have a existence of its own that defied the human will to control it."[2]

A Case Study: The Eastland Disaster

Looking at historical cases involving unintended consequences is a useful methodology for students to practice critical thinking and ethical problem-solving skills. When the Titanic sank in 1912, a hue and cry of "boats for all" resounded from both sides of the Atlantic. The disaster spawned a number of new laws, including a compulsory 24-hour wireless watch, the establishment of the International Ice Patrol, and the movement of shipping lanes further south to avoid rogue icebergs calving from the Greenland iceshelf. By far the most significant, however, was mandating lifeboat or liferaft seating for all passengers and crew.

As good as that law seems, however, it resulted in devastating, unforeseen consequences for the Great Lakes excursion ship, the Eastland, which, on July 24, 1915, rolled over while docked at the Chicago River. More than 800 people were trapped below decks and drowned or suffocated. The disaster impacted the collective psyche of Chicago to such a degree that it was more or less forgotten, until the 1998 establishment of the Eastland Disaster Historical Society.

The Eastland disaster is a perfect example of "social amnesia," as Ted Wachholz, author of *The Eastland Disaster*, suggests.[14] It is also an excellent illustration of unintended consequences, specifically, how a "good" action resulted in unforeseen "bad" outcomes.

Background

July 24, 1915, dawned grey and overcast in Chicago, with rain imminent. The weather, however, did little to dampen the high spirits of Western Electric Company, Hawthorne Works, employees, who were dressing to the nines for the annual company picnic in Michigan City, Indiana. By 6:30 a.m., seven thousand workers were streaming towards the Chicago River, to board five excursion vessels that Western Electric had rented to ferry its employees across Lake Michigan to a resort area in Michigan City, Indiana.[15]

The excursion trade was big business around the turn of the nineteenth century. For a modest fee—75 cents on the Eastland—lower middle class workers could spend a few hours living the high life to which they aspired. Shipping companies ran relatively light ships that sat high in the water, to make the crossing quickly.

The Eastland, built in 1903, soon developed a reputation as a "cranky" ship; she was unstable, especially during loading and unloading, and passengers often complained of seasickness.[15] The stability issues were reflected in the fluctuation of passenger load, as indicated in Table 1.

Table 1. Eastland passenger loads[15, 16]

Year	Number of passengers
1903	2,800
1904	3,300
1905	2,907*
1906	3,000
1907	2,400
1908	1,950* 2,200 2,400

1909	2,000 2,200
1913	2,000*
1915	2,500

* Reductions due to legislation

Continued lateral instability was attributed primarily to engineering issues, particularly the ineffectual ballast system, which had intake and outtake valves located on the starboard side. Any significant list to port could theoretically render the ballast system inoperable, as the intakes would be above the water. In addition, intakes and outtakes used the same manifold, which made simultaneous operations impossible. And, finally, because the tanks were built along the hull contours, they were different sizes; the entire system took about one hour to fill.[16] If partially filled, which was typical, the water sloshing around augmented the instability.[17]

Adding to the instability were certain modifications made in 1914 in order to make the ship more attractive and profitable: sagging wooden floors midship were replaced by more durable concrete, and the aft gangway had an extra layer of concrete, for a combined total of 57 additional tons.[17] And to meet new legislation passed in the wake of the Titanic disaster, 11 lifeboats and 37 rafts were added to the topmost deck, for another 10 tons;[17] 2,500 lifebelts added another 6.5 tons, since each weighed 6 pounds.[15] Simply put, the Eastland was dangerously top-heavy.

Precursor Events

In retrospect, the 1915 Eastland disaster seems almost inevitable, considering her past: originally envisioned as a freighter, the ship was designed to be longer and shorter. When financing proved questionable, 60 feet were removed from the midsection design plans, affecting transverse stability (the "metacentric height"),[16] and a deck was added to increase profits from passenger travel, affecting the center of gravity. In addition, gangways were placed one deck lower than what was typical for the time and fitted with half-doors; the top halves were left open, allowing water to enter with even a slight list.[16]

Consequently, in 1904, just five minutes out into Lake Michigan from South Haven, Michigan, the Eastland began to list 15º to port; enlisting the ballast system, engineers managed to right her, but she then began listing to starboard. For 25 minutes the ship alternated rolling from port to starboard, sickening a number of passengers and prompting others to don lifebelts. She arrived in Chicago 40 minutes late, with ashen-faced passengers.[16] In 1906, a less frightening incident occurred; the ship left her Chicago dock listing starboard but was righted before reaching Lake Michigan. Despite these two incidents, her safety factor was deemed acceptable.[16] Even more disturbing is the incident that happened the day before the roll-over: 20 miles out on Lake Michigan, on an excursion to St. Joseph, the ship suddenly listed more than 20º to port before righting itself, causing many passengers to become ill and anxious.[14]

With this prior history of instability, it should have come as no surprise that the additional life-saving—and very heavy—devices required by legislation following the Titanic disaster made the already-unstable vessel even more so. In fact, Sydney Charles Buxton, president of the British Board of Trade, which was responsible for the “boats for all” regulations in Great Britain, declared in an April 1912 meeting of Parliament, “if you overload the vessel with boats, the real danger in the case of emergency would be that the very number of boats themselves might lead to disaster.”[16]

Echoes of his warning also appeared in *The Marine Engineer and Naval Architect,* in an article commenting on the report of the Board of Trade’s Merchant Shipping Advisory Committee, “there is a danger of making ships too tender if extra weights are placed on the boat decks,”[16] as well as in A. A. Shantz’s testimony before a Congressional committee considering passage of the La Folette’s Seamen’s Act, the “boats for all” legislation under consideration in the United States. As general manager of the Detroit & Cleveland Navigation Company, Shantz had a vested financial interest in the outcome; however, he also voiced concerns for passenger safety: “The extra weight of lifeboats and rafts would make them [the Great Lakes steamers] top-heavy and unseaworthy, and in our judgment, we believe some of them would turn turtle if you attempted to navigate them with this additional weight on the upper decks.”[16]

These warnings were to become reality for the Eastland on the morning of July 24, 1915, as she sat at dock in Chicago.

The Incident

The Western Electric Company, born with the invention of the telegraph, by 1915 manufactured equipment to support the burgeoning telephone industry. Hawthorne Works, located in what is now Cicero, Illinois, was the company’s largest facility and promoted a “paternalistic, family culture,”[14] supplying its employees with many amenities, including sports clubs, athletic fields, a restaurant, a band shell, stores, and a library. Most of the Hawthorne employees were Eastern European immigrants, primarily Czech and Polish, who not only worked together but lived side-by-side in close-knit communities. The annual summer picnic was a bright point in the season; in fact, a common saying in the factory was “summer was invented . . . especially for the annual picnics of the Hawthorne employees.”[14]

On July 24, the mood was festive, despite the dreary weather, as 2,500 Hawthorne employees and their families boarded the Eastland. Tradition dictated that they dress in their finest, wearing their best jewelry and furs. Because of the drizzle, most moved below decks, where a band was playing and couples were dancing to spritely ragtime music—foreshadowing the good times anticipated at Washington Park, where a resort area featured bathing and picnicking on the lakeshore, an amusement park, and a baseball field.[14] They laid claim to spots below, stashed their picnic baskets, and proceeded to mingle with friends.

In preparation for the trip, the Eastland had taken on some 104 tons of coal the night before. Rather than equally distributing it in the bins located on both sides of the ship, 79 tons were loaded on the port side and 24 tons to the starboard.[17] The ship’s stability was thus compromised before any passenger set foot aboard.

By 7:10 a.m., the engines were running, the aft lines had been cast off, and ship had drifted about 20 feet from the dock. It developed a 7° list to port, noted by the captain, who ordered the engines stopped. In a mere five minutes, the list increased to 15º and by 7:25, it had increased alarmingly, to 25-30°. Distressed, crew members shouted to passengers still on deck to move starboard, although the angle, coupled with the wet deck, made any movement difficult. By 7:31, it was all over: the port list reached 45º, and the Eastland "just rolled over like an egg in the water," observed traffic policeman Fred Fischer who, just a few minutes earlier, was helping to load the passengers.[16]

Passengers above decks had a choice to make: to dive for the pier or the tugboat near the Eastland, where, if they were lucky, observers pulled them to safety, or to jump into the river. Although relatively shallow, the Chicago River was undoubtedly the worse choice, as it had served for decades as a dumping ground for the city and was fetid with pollution, both human and animal, a "rancid tide of filth."[15] Harlan Babcock, a reporter for the *Chicago Herald*, vividly described the scene in the river:

> The surface of the river was black with struggling, crying, frightened, drowning humanity. Wee infants floated about like corks. Shrieks and cries of "Help" from those in the water filled the air. Many sank instantly and were seen no more. Others tore off their clothing in the water as best they could and tried to swim for safety. Some succeeded. Others turned white, imploring faces toward the panic-stricken crowd on the bridges and piers, but before help could reach them sank to watery graves.[15]

Below decks, chaos reigned. Passengers, weighed down by their clothing, tried to reach the open gangways, now located above them. Portholes clogged with people trying to push their way out. As post-incident interviews with survivors revealed, survival was more a matter of luck than anything else; Clara Reisner reflected, "We were just at the right place at the right time," the "right place" being the starboard side of the ship. Those on the port side were doomed, either drowned by the sudden influx of water or suffocated by the weight of debris and people pinning them down.[14]

All told, 844 people, including 22 entire families, perished in 20 feet of water on that rainy July day, despite heroic, albeit disorganized, efforts to save them. Divers risked their lives prowling through the massive hulk, and welders above cut holes in the side of the ship for rescuers to enter. Most of those recovered, however, were dead. It was truly a heart-breaking, soul-shattering scene.[15]

Aftermath

In some ways, the aftermath was even more gruesome than the incident itself. Victims were taken to the nearby 2nd Regiment Armory (now home to Oprah Winfrey's Harpo Studios).[18] Relatives and interested others lined up to enter and identify the dead. Unfortunately, those "interested others" also included thieves: the victims' bodies were rich pickings, as they were laden with jewelry and fine clothing. Continuous wakes occurred in Cicero neighborhoods, and thieves entered those premises as well, stealing valuables while families were mourning.[14, 15]

Legal wrangling began shortly after the disaster in both criminal and civil venues; the civil cases lasted up to 20 years. In the criminal case, four officials of the St. Joseph-Chicago Steamship Company, the registered owner of the vessel, were indicted on numerous charges, including manslaughter, and two of the ship's personnel, Captain Harry Pederson and Chief Engineer Joseph Erickson, were indicted on charges of "criminal carelessness." The presiding judge eventually reduced charges against all principals to "conspiracy to operate an unsafe ship."[16]

The defense attorney for Erickson was the not-yet-renowned attorney Clarence Darrow, who waged a vigorous defense based on the assumption that the damage to the Eastland was the result of some underwater obstruction, either the remains of a collapsed building or old pier pilings. Although the argument made logical sense, further testimony indicated that other ships, with deeper draws than the Eastland, had recently used that dock without incident.[16]

Ultimately, in both criminal and civil trials, the defendants were acquitted of wrongdoing, based on the conspiracy charge. No one served jail time, and the only compensation was adjudged at $50,000, the estimated value of the Eastland's hull. But after paying off debts, including $35,000 to raise the ship from the river, nothing was left for the victims' families. "Perhaps," suggests Ted Wachholz, co-founder of the Eastland Disaster Historical Society and husband of survivor Bobbie Aanstad's granddaughter, "one of the biggest tragedies as a result of the Eastland disaster was that there was virtually nothing paid out to the families as a result of the tragedy."[19]

Analysis

On a technical level, the Eastland disaster is an excellent example of unintended consequences. While the outcome of adding more than 50 tons of weight midship and misapportioning the distribution of coal is somewhat predictable, especially considering the ship's history of instability, the additional 17 tons on the top deck, mandated by the change in lifeboat requirements resulting from the Titanic disaster, was quite literally the tipping point for the Eastland.

The disaster is an example of a reverse effect: the intention of the law was to save lives, but, in the case of the Eastland, lives were lost. Ironically, those life-saving devices were never used: the lifebelts were safely stowed in locked crates, and the roll-over occurred too quickly to even consider launching lifeboats.

Tenner might view this incident as a revenge effect, as, ultimately, it superseded people's ability to control the technology. Revenge effects occur because "new structures, devices, or organisms react with real people in real situations in ways we could not foresee."[2] Not a soul associated with the Eastland envisioned the scenario which took place, just as the hubris displayed by the White Star Line dismissed the possibility of the Titanic foundering. Once in a particular situation, however, "things" took on a life of their own, and humans died as a result.

Unintended consequences also occurred on a more human level: while it is within the realm of imagination to foresee thieves lurking in the armory, passing themselves off as relatives to steal from the dead, who could possibly anticipate that they would actually enter houses of mourning and carry off items like paintings and furniture?[15] Such uncivil and cold-hearted actions are inconceivable in civilized society. Likewise, the avaricious undertakers who took advantage of the bereaved by substantially increasing prices of coffins[15] displayed relatively inhumane behaviors in the presence of so much death, although, in a capitalistic society, greed is a predictable outcome.

Contemporary Examples

Current examples of unintended consequences abound in a variety of fields. Having students examine what has happened as a result of the computer revolution offers an eye-opening look at the effects of a technology that is now ubiquitous, one which more or less controls our students' academic experiences, let alone their daily lives. We will limit our comments to just two unforeseen effects of the Internet, which was originally developed to provide scientists a convenient means of communication.

While some effects of the Internet, such as the overwhelmingly commercial orientation, are quite predictable, others are not, especially those involving interpersonal relationships. By connecting to the Internet in a home environment, we are inviting friends to share our lives, but unsavory characters enter as well, as NBC's *Dateline* series, "To Catch a Predator,"[20] so graphically illustrates. The Internet, in fact, has a tendency to exacerbate uncivil behavior, as John Seabrook eloquently describes in his elegiac meditation, *Deeper*. Seabrook started his two-year journey for an electronic utopia as an optimist, viewing the Internet as the one truly egalitarian communications medium that would allow for a meeting of mind: the "many to the many" instead of the "one to the many," as is the case in more traditional, print media. What he discovered, however, is that the classless nature of the Internet lets in the howling masses as well as the enlightened: "Whatever capacity the medium has for bringing people together, it has an equal capacity for driving them apart; and the solace one may find on-line is offset by malice, and the compassion by cruelty, and the goodwill by spite."[21]

The Internet has also provided a convenient venue for various scams. Some, such as the Nigerian 419 fraud letters, certainly existed prior to the Internet,[22] although an electronic medium has allowed scammers to reach a vast audience and cast a very broad net. Others, such as phishing, are peculiar to the Internet[23] and certainly qualify as unintended consequences: phishing is an identity theft technique whereby scammers create very realistic-looking counterfeit websites, usually those for banks or popular sites—eBay or PayPal—or even government agency sites, such as the IRS. Users clicks on a link in an initial email to access the site and respond to a prompt to enter sensitive information: social security number, ATM PIN, mother's maiden name (the key to unlock credit), etc. The scammer then uses that information to purchase high-ticket items or vacuum out accounts.

These two effects constitute the revenge of a medium so complex and intransparent that it is becoming impossible to control. As with all complex systems, the Internet has multiple variables, both identifiable and unknown. Its very complexity nearly defies understanding. Blogger Scott Cleland likens it to a brain: "The Internet's complex ganglia of technologies, networks, agreements, standards, incentives, collaborations, contracts, innovations, relationships, safeguards, protections, economics, etc.—approaches the complexity of a brain,"[24] echoing

Marshall McLuhan's 1967 definition of "electric circuitry" as an extension of the human nervous system.[25]

It's a long way from a consideration of a 1915 boating incident to examining the high-tech world of computers. However, each serves as fodder for contemplating those effects that we cannot predict but must somehow incorporate into our lives once they have emerged.

Classroom Suggestions

"Since the time that Prometheus stole fire from the gods and gave it to mankind," declares J. Douglass Klein, dean of interdisciplinary studies at Union College, "technology has created a dilemma, providing benefits but posing risks. Often the benefits are initially more evident than the risks, but risks should be weighed. Engineering students need to expand their concept of a 'system' to include the social implications of their designs, even when those implications may be foreseen only dimly."[26] While the Prometheus metaphor is perhaps a bit fanciful, Klein's observation that engineering students must also become ersatz sociologists is appropriate to the current technical educational climate.

Studying unintended consequences allows students to examine both social and ethical effects of the technology that they will create. While unintended consequences are by definition unpredictable and unforeseen, thereby precluding an analysis of the effects of emerging technologies, looking at the now-known unintended consequences of technology can hone problem-solving skills in both engineering and ethics. The following exercises are useful:

Brainstorming

Divide the class into small groups (4 or 5 to a group is optimal). Have each group select a topic from a prepared list of technological devices. In developing the list, try to choose items that students are quite familiar with, such as cell phones, massively multiplayer online role-playing games like World of Warcraft or Halo, microwave ovens, Wiis, etc. Have each group brainstorm three lists: benefits, drawbacks, and unintended consequences that have been identified since the appearance of the device. After developing lists, have the groups report back to the entire class. With the topic of cell phones, for example, students generated the following in a 10-minute session:

Benefits include "instant communication," "readily available," helpful for emergencies," "can check on children's activities," "helps with shopping," "love that texting feature!"

Drawbacks include "billing for extra minutes," "confusing plans," "having them go off in class is annoying," "I don't like eating out and having to listen to someone else's cell phone conversation," "my alarm goes off whenever it wants to," "too many upgrades," "too expensive."

Unintended consequences were, naturally, more elusive, and identification requires that students be somewhat familiar with the literature written about the device. While the group struggled with this item, one alert student, who had read about our state's recent legislation banning all but "hands-free" devices while driving, wondered if that law would solve the problem of distraction.

Ironically, it happens that a recent study dealt with that very issue: as reported in the *Journal of Safety Research*, Canadian researchers Yoko Ishigami and Raymond Klein discovered that using any type of cell phone (hands-on or hands-free) while driving distracts the user from the road, resulting in slower reaction times, slower vehicle speeds, and increases the possibility of accidents.[27]

Class Discussion

If time for small groups is not available, consider a variation of the brainstorming technique and engage the entire class in conversation about one topic. If the class is reluctant, instructors can jumpstart the conversation by asking students to talk to their neighbors for one or two minutes about the topic.

Another approach is to piggy-back a discussion of a case involving unintended consequences with a similar case. In my ethics class, for example, students study the Titanic to practice identifying ethical issues. Introducing the Eastland disaster immediately following illustrates the common link between the two cases as well as their interdependence: had the Titanic not sunk, the Eastland would have still been “cranky,” but it probably would not have rolled over because the extra weight on the top deck—a direct result of the Titanic disaster—would not have existed. Between the two incidents, more than 2,300 people would have continued their lives.

Research

Research projects can vary in length and intensity, depending on class goals, and they can be solo efforts or group affairs. Try to avoid very complex cases, such as the Bhopal gas leak; smaller cases, such as the Eastland or the Iroquois Theatre Fire of 1903, are more manageable in a limited timeframe, especially if each student is working on a different project. Results can be conveyed to the class via written summaries, formal presentations, or informal class discussions. For instructors less keen on grading written reports, consider substituting an annotated bibliography; these take less time to evaluate and still indicate that students have done sufficient research.

Conclusions

Unintended consequences are elusive creatures and naturally follow from the introduction of new technologies, actions, and decisions. And technology, particularly complex systems, can exhibit decidedly quirky characteristics. If technological determinists such as Neil Postman are correct, any technological change results in profound disruptions, some obvious, some not: “New technologies alter the structure of our interests: the things we think *about*. They alter the character of our symbols: the things we think *with*. And they alter the nature of community: the arena in which thoughts develop.”[28]

In terms of pedagogy, the topic of unintended consequences introduces students to a neglected area of ethics studies and engenders a certain anxiety: how can they possibly design something to avoid circumstances that won’t even exist until that thing is used? However, as Henry Petroski suggests, engineers should be anxious during the design phase; they should lose sleep worrying. To quote Lev Zetlin, a structural engineer known internationally for his innovative design:

> Engineers should be slightly paranoic during the design stage. They should consider and imagine that the *impossible could* happen. They should not be complacent and secure in the mere realization that if all the requirements of the design handbooks and manuals have been satisfied, the structure will be safe and sound.[29]

Concern for design, Petroski recommends, "should be worn by the profession as a badge of honor."[29] Acquainting students with the concept of unintended circumstances in an academic environment may result in more sensitive, aware, and visionary professionals.

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