



## PAPER REDUCTION AT WPI

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An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

SUBMITTED BY:

Jivesh Tolani

[tolanij@wpi.edu](mailto:tolanij@wpi.edu)

SUBMITTED TO:

*project advisor*

Prof. Fred Looft

[fjlooft@wpi.edu](mailto:fjlooft@wpi.edu)

# Abstract

The purpose of this project was to develop recommendations to reduce paper consumption at WPI. This project initially looked at the primary drivers of paper use within the WPI community and the reasons why, in spite of modern information processing capabilities, the current practices still use an increasing volume of paper. Leveraging the latest technological offerings to counter human preferences for paper emerged as the cornerstone of the ultimate solution.

The institute's core Blackboard implementation of myWPI is recognized to have much of the infrastructural capabilities to drive a paperless education model. However, inconvenient human-machine interfaces drive both students and faculty to print most of the information that actually resides on computer storage within and outside WPI as well as opt for printed text books.

This effort has identified a practical and attractive initiative that leverages the recent advances in tablet computing and cross platform data synchronization to deliver even better portability than paper offers in the educational environment. The use of tablets also provides the very conventional and preferred option of hand written annotation, a feature that, thus far, has only really been available with paper.

More specifically, this report lays out the requisite enhancements necessary to the institute's network storage system available to students, as well as a couple of add-ons that will interface with the excellent myWPI core to provide faculty with offline access to student submissions on tablet devices and then replace the original submissions on myWPI with the graded copies so that students can access their graded work through the myWPI portal.

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# Table of Contents

Chapter 1: Introduction	1
1.1 Project Statement	2
Chapter 2: Background	3
2.1 Introduction	3
2.2 Paper	3
2.4 Technologies	7
2.6 Summary	19
Chapter 3: Data Collection	20
3.1 Introduction	20
3.2 Student Survey	20
3.3 Faculty Interviews	22
3.4 Summary	24
Chapter 4: The Way Forward	25
4.1 Introduction	25
4.2 Paper Reduction Solutions	25
4.4 Summary	29
Appendix 1: Student Survey	30
Work Cited	33

## Chapter 1: Introduction

Paper has historically been a major medium for the recording and transmission of information. It provides a means to record, present and disseminate information. Due to its availability, portability, durability and annotation possibilities, and its being relatively inexpensive, paper has become the favored medium for many applications: printing books, distributing information and news, sending mail, and taking notes, to name a few.

That being said, despite the ease associated with paper use, its environmental and financial impact over time merit serious concern. Furthermore, with the population's continuing growth in both size and collective knowledge, it is understandable that the consumption of paper has increased, and will continue to increase, unless paper's functionality can be replicated through some other means.

As an educational institution, WPI uses paper for various applications including, but not limited to, textbooks, class handouts, assignments, notes, exams and course evaluations. It is therefore reasonable to expect that the WPI community will grow in the years to come and will also have to deal with ever-increasing volumes of recorded information. Institutions like WPI also need to respond to such growth patterns in the quantum of information and the continuing need to educate a growing population. Absent any changes in present day practices, paper consumption can be expected to grow in response to both drivers of the educational activity - a growing knowledge base and student body.

While paper fills a very useful role in a convenient manner, the increase in the amount of paper being used poses challenges. Perhaps the most pressing challenge is that these volumes of paper must eventually be archived or disposed off. Both of these have associated costs, resource requirements and environmental implications. It is therefore both an economic and environmental imperative for an institution like WPI to moderate the consumption of paper within its domain of influence.

Fortunately, with advancements in technology and the development of innovative new products it is becoming increasingly possible and convenient to reduce or replace the use of paper. Exploiting the possibilities of these new developments would not only reduce paper consumption, and therefore the associated costs of archiving or disposal, but also yield other benefits of efficiency and improved effectiveness in various processes that are the foundations of education.

We acknowledge that setting a goal to eliminate paper from our lives is unreasonable. A change so drastic would require too extreme a change in the lifestyle of the average person. It would be nearly impossible to implement a policy that ceases paper-use; however, it is imperative that address the issue of paper over-use. The hope is that, in considering specific technologies and methodologies to reduce paper use, we will discover reasonable and implementable alternative methods to record, distribute, and display information. Ultimately, we hope to develop a paper-reducing strategy that will allow us strike the perfect balance between depending exclusively on paper and eradicating it completely, thus lessening the environmental and financial consequences of paper use without losing the associated convenience.

The implications of this strategy for WPI, specifically are remarkable. A reduction of paper at WPI would lead to a smaller carbon footprint for the institution. It would also reduce costs over time, while setting up the infrastructure for better integration of technology in the education process.

## **1.1 Project Statement**

This Interactive Qualifying Project (IQP) seeks to examine:

- the role of paper in the education process,
- work processes at WPI as drivers of paper consumption,
- technology and process solutions that can be economically and conveniently exploited to achieve significant reduction in paper consumption by the WPI community,
- preferences and work habits of constituents of the WPI community that would affect the practicality of implementing solutions

and recommend suitable initiatives for implementation at WPI to save paper and put the institute on a track that reduces future institutional costs, is environmentally friendly in the long term and improves educational efficacy.

# Chapter 2: Background

## 2.1 Introduction

This section first presents an overview of paper, including how paper is produced and subsequently disposed of, so as to appreciate the environmental impact of its life cycle. Thereafter, it examines the role of paper in education to provide a basis for identifying the requisite characteristics and qualities required of alternatives that would be effective in replacing paper in educational processes. Finally a review of the progression of technologies and relevant products that are related to both paper consumption and reduction, provides the building blocks for developing solutions for reducing paper consumption.

## 2.2 Paper

### *Necessity for paper*

Before the development of written language, there was no means by which to physically record knowledge. Instead, knowledge was passed on orally or by demonstration, and was also gained by experience. After the development of written language knowledge could be recorded, providing a more reliable way to more accurately preserve information. In the beginning the medium for the writing was stone, which was extremely difficult to mark and had severe limitations in respect of distribution. As man developed more advance mediums and instruments with which to write, recording information became easier, faster and more economical. These benefits provided major advantages to societies development, particularly in communication and information-based activities such as the process of education Paper allowed for information to be distributed more easily as manuscripts and books, were able to eclipse oral history as the primary method of spreading knowledge in the classroom. However, its contributions to education do not stop there.

In addition to distributing information, an important component of the education process is the evaluation of students' learning. Prior to the advent of paper and its precursors, evaluations could only be conducted verbally or by observation. Paper and writing enhance the process by making evaluations far more efficient and easier to conduct, providing quick and precise feedback through activities ranging from assignments to examinations. As we have progressed through the information age, paper has become a key resource for humanity, a fact demonstrated by the exponential expansion in consumption.

### *Invention*

Paper is a substance comprised of cellulose, a natural plant fiber . Though these fibers can come from a variety of sources including cloth rags and grass, modern paper is almost exclusively made from wood. Although usually thought of primarily as thin sheets of these fibers pressed together, paper is also used to make thicker products such as cardboard (Fuller 2002).

Paper was first created from macerated vegetable fibers in porous molds in China in 105 AD. Much of the paper for the next 200 years was made from the vegetation, cloth and tree bark. The technique for making paper traveled to Japan and Korea through numerous trade routes, but remained in South East Asia until the Chinese lost a battle to Turkistan in 751 AD. Many of the Chinese captured during the battle were skilled paper makers and began making paper in the Middle East. From there, paper was exported and soon became the principal material to write on. It wasn't until the 11th century however, that Europe began producing paper (Fuller 2002).

### *Manufacturing and Recycling*

The modern process of making paper begins with cutting the wood into small chips. The chips are then mixed with hot water and chemicals such as sodium hydroxide and sodium sulfide to separate the fibers. This yields a pulp that is then mixed with more water, and sometimes additional pulp created from recycled paper products, to create a slurry. This slurry is then sprayed on a wire mesh screen that is run through a paper machine. The machine uses rollers to squeeze the water out of the pulp, and make it smooth. Heated rollers then dry the paper before it is cut into the desired size ("Paper University: All About Paper" 2001).

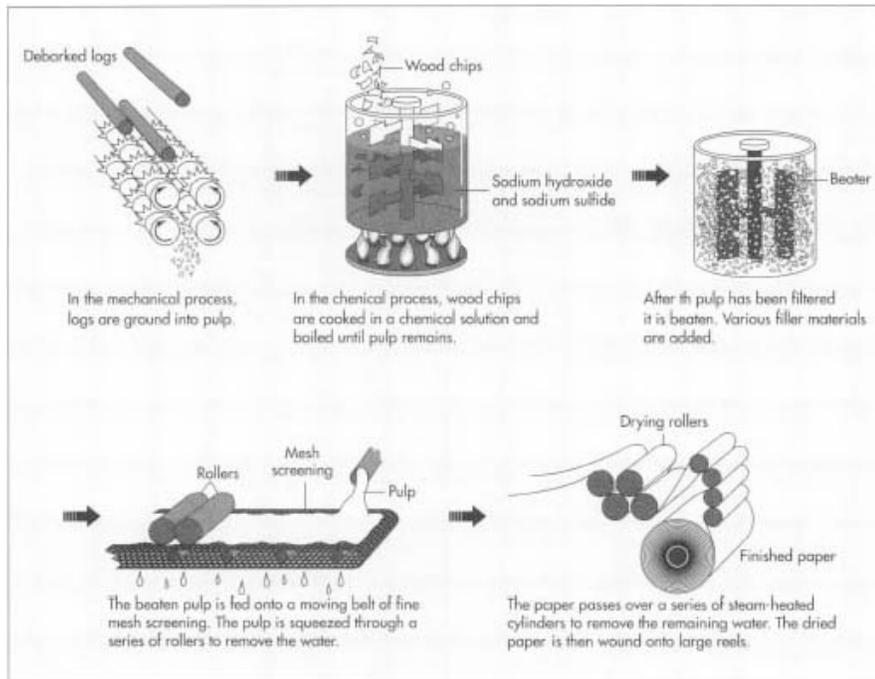


Fig 1. The paper manufacturing process.

source: <http://www.madehow.com/Volume-6/Wrapping-Paper.html>

To create the recycled pulp that is sometimes used in paper production, consumed paper is ground into pulp and subjected to a “de-inking” process. De-inking usually uses chemical dispersants, detergents and bleach to remove ink and other impurities like stickies. The recycled pulp is then mixed in with virgin pulp to be produced into paper. Therefore, even recycling has its limitations where sustainability is concerned ("Paper University: All About Paper" 2001).

One of the key factors that determine the quality of the paper produced is the length of the plant fibers. During the manufacturing process these fibers become shortened and, after recycling, become shorter still. With shorter fibers, the resulting paper is weaker, less durable, and prone to relatively faster degradation and disintegration. For this reason it is impractical to make pure recycled paper, and nearly impossible to recycle the same fibers after a certain point ("Paper University: All About Paper" 2001).

### *Consumption*

The average American consumes more than 340 kilograms of paper a year (“Facts about paper and paper waste”). To put this into perspective, this is about the equivalent of a tree that is 100 feet tall and has a trunk with an 18 inch diameter (“Facts about paper and paper waste”). Although this may seem like a modest resource requirement, the total forested area needed to produce the yearly paper consumed in the US equates to a little over 307 million trees, or about 440,000 acres of forest (“Facts about paper and paper waste”). In comparison, the entire state of

Rhode Island has only 393,000 acres of forest land ("Land Acreage: total forest land statistics." 2004). Thus, an area representative of more than the entire forested area of Rhode Island needs to be harvested to meet the US paper consumption demand for just one year; and this statistic only exemplifies one aspect of the impact that the paper industry has on the environment.

In addition to the trees harvested annually for paper production, the industry is responsible for about five percent of the toxins released into the air, water and land ("Toxics Release Inventory Data for Pulp and Paper (SIC Code 26)"). It is also one of the few industries that has not reduced the amount of toxins released since 2001 ("Toxics Release Inventory Data for Pulp and Paper (SIC Code 26)"). The paper manufacturing industry is also the third largest consumer of fossil fuels in the world ("Facts about paper and paper waste"). Beyond the environmental impacts posed by the manufacturing of paper, both recycled and new, the disposal of paper in landfills contributes to the production of methane gas through decomposition of landfill contents. Unfortunately, methane is a greenhouse gas that traps more heat than carbon dioxide. Landfills account for roughly twenty-two percent of US methane emissions making them the second largest source after enteric fermentation ("Sources and Emissions|Methane" 2011). This means that paper accounts for roughly 5.5% of total US methane emissions since paper makes up about 25% of landfills ("Solid Waste Management and Greenhouse Gases" 2002). As a result landfill waste from paper products likely contribute significantly to global warming.

### *Impact of Recycling*

Recycling is said to not only reduce the number of trees needed to produce paper, but also reduce water and energy usage. "Paper manufacturing is the largest industrial user of water per pound of finished product" ("Facts about paper and paper waste"). The Environmental Protection Agency (EPA) reports that recycling paper reduces water pollution by 35 percent, and air pollution by 74 percent ("Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2008" 2008). Unfortunately, there is much dispute over how much energy is actually saved by recycling paper.

The Bureau of International Recycling (BIR) is a non-profit organization that strives to promote international recycling in an effort to conserve natural resources. It reports that recycling pulp uses up to 64 percent less energy compared to producing virgin pulp("About Recycling" ). In contrast, a study performed in the Biotechnology Center at the University of Wisconsin indicates that recycling can require even more energy than creating virgin paper (Jeffries 1997). The contradictions in energy use estimates lie in the various types of paper recycled and the processes used to recycle them.

Friends of the Earth, an organization dedicated to protecting the environment, has conducted a study into paper recycling and the misconceptions associated with them (MacGuire

2001). This study explains that the amount of energy saved varies based on a multitude of factors including the quality of the paper, the milling processes used, and the transportation of the paper. The study also notes that forest products industries often exclude the energy required for maintaining, harvesting and transporting timber from their energy analysis. Due partially to the inconsistencies in measuring energy usage, there is unfortunately no definitive method of determining the actual environmental impact of recycling paper.

Another factor that is often not taken into account while considering the costs “saved” by recycling paper include: the need for managing forests, particularly in a large systems sense in terms of the need for carbon reducing green vegetation; the possibility that fertilizer run off from managed forests can pollute streams and other down stream bodies of water; and related considerations not perhaps directly related to wood pulp forest management, but part of the paper production system. While we acknowledge the potential need to consider such system impact factors, we will not address them as part of this report.

## **2.4 Technologies**

### *Paper-centric*

Inventions and developments of paper related technologies throughout history have contributed to our ever-increasing paper consumption. When the printing press was invented, it enabled a quantum leap in paper usage. It allowed for large scale production of paper records, making mass distribution of information significantly more viable. The printing press resulted in a sharp decrease in the cost of producing books, quickly making them available to the masses. This led to a significant rise in literacy, making books one of the most viable tools for large scale education (Kreis 2004).



Fig 3. A 15th century printing press similar to the one Gutenberg invented.  
Source: <http://iml.jou.ufl.edu/projects/fall04/phillips/index.html>

The typewriter became one of the first inventions to allow individuals to cheaply and rapidly produce print-quality documents. It led to an increase in paper consumption, especially in offices, and was one of the biggest benefits to professional writers. By allowing users to create unique documents much faster than they would be able to by hand, the typewriter led to more intensive use of drafts and greater productivity, but also led to increased use of paper.



Fig 2. Prototype of the Sholes Typewriter  
source: <http://upload.wikimedia.org/wikipedia/commons/9/9a/Sholes typewriter.jpg>

The photocopier, preceded by the mimeograph, both provided a low cost, rapid way to duplicate of documents. It meant that almost anyone could afford to conveniently reproduce documents for large audiences. In the educational setting, it meant that professors could easily distribute their own materials tailored to the particular needs of their courses. These materials, such as professor notes, instructions and other handouts, benefit the student's learning, and provide the ability to more easily create assessments items, like homework and exams which led to more efficient and customized evaluations.



Fig3. The Xerox 914 photocopier  
source: [http://upload.wikimedia.org/wikipedia/en/b/b7/Xerox\\_914.jpg](http://upload.wikimedia.org/wikipedia/en/b/b7/Xerox_914.jpg)

The aforementioned advances in technology steadily provided increasing information processing capabilities to mankind, and thereby the means for faster and more intensive flow of information in academia. In the context of education this meant the ability to transfer more information amongst the constituents in a faster manner. This has also aided the process of research, education and testing. However, all this advancement has been accompanied by a commensurate increase in the demand for and consumption of paper.

### *Personal Computing*

The personal computer was one of the first data centric technologies that did not directly require paper. With its growth came an expectation of a dramatic reduction in the use of paper, especially as connectivity increased through networks, the internet, and email. The first PCs however, were not very reader-friendly, and lacked some of the significant benefits of paper. Viewing anything more than a page on a computer monitor was relatively inconvenient from the beginning. Some other factors that made computers a poorer alternative to paper for reading included:

- Poor display quality, including flickering of cathode ray tube (CRT) monitors, which led to eye strain.
- Lack of portability of the computer and monitor.

- Non standard aspect ratio of computer displays compared to a standard formatted document.
- Challenges in annotating the material read.

Consequently, through the first 30 years of the personal computer age, people have shown a growing willingness to manipulate and distribute written documents on computers. That being said, many people still do their serious reading and evaluation on paper, requiring the printing of documents and data stored on computers. Driven by this continued demand for the printed page, manufacturers have continued to develop faster, more capable and less expensive printers to be used by consumers. This coupled with the ease of printing computer-stored material has made mass production of printed documents a relatively trivial matter, thereby generating more paper based output at steadily decreasing personal costs. The convenience and economy of distributing vast amounts of information electronically, and ease of printing at each receiving node, has led to a veritable explosion of paper consumption instead of the initially expected reduction in paper consumption.

At the same time, electronic storage of information was not enough of an economically compelling option due to the relatively high cost of storage devices like hard disk drives. However, the problems of dealing with large volumes of paper were substantially reduced using microfilm technology with some attendant compromises in handling and distribution.

#### *Current state of the art hardware*

After this false start for paper reduction there have been recent developments that have brought technology, products and services, with some real potential to reduce paper use, to the consumer market.

Fortunately, with developments in technology, the cost of data storage has been decreasing exponentially, and the benefits of utilizing mass storage systems are multiplying. For example, in the last 20 years alone, the price per gigabyte of data storage has gone from \$12,000 in September of 1989, to only 7 cent as of July 2008 (Komorowski 2009). To compare, one can estimate the cost for printing 340 kg of paper at \$2,800 ("Cost of Ink Per Page Analysis United States" 2010), significantly higher than the cost of an entry level computer, that can store all the data printed on that paper. Furthermore, digital storage being readily available, storing documents in digital form is much more cost effective than storing physical sheets of paper or less readily accessible microfilm, and provides for easier editing, search, distribution and duplication.

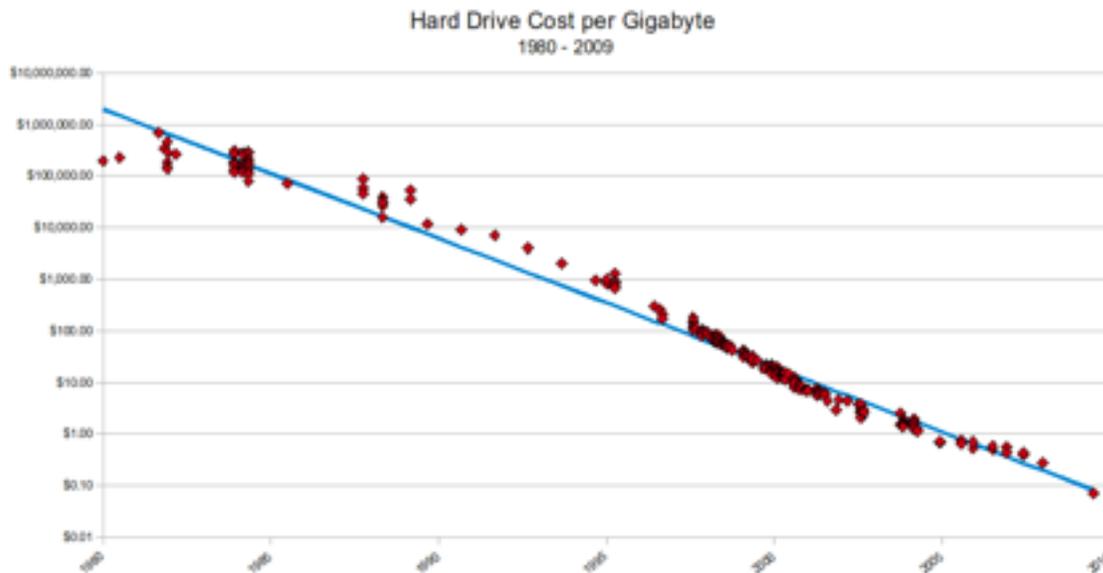
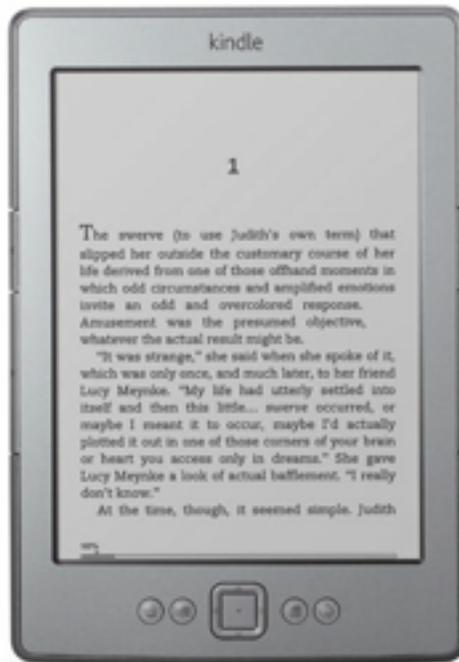


Fig 4. Hard drive cost per gigabyte over time  
 Source: <http://www.mkomo.com/assets/hd-cost-graph.png>

One of the more significant improvements in the user experience has been in display technology. Liquid Crystal Displays (LCD) and Light Emitting Diode (LED) screens addressed major issues with CRT monitors. Manufacturers have increased the refresh rate, removing any noticeable flickering, and made screens significantly thinner and more portable. Another newer display technology, electronic paper, is designed to closely resemble ink on paper, and is targeted towards reading applications. Unlike LCDs, e-paper displays only use power when updating the screen. Charged particles colored black and white are drawn to the surface of the screen by means of an electric field generated by the device. When the electric field is disabled, the particles remain in place. This not only results in significantly lower power consumption compared to an LCD screen, but it also eliminates the need for a backlight which allows easy readability in bright lighting conditions.

Electronic paper displays are being used in a number of devices dedicated to reading electronic books and documents. Probably the most prominent of these eBook readers is the Amazon Kindle. Amazon's latest Kindle supports not only a multitude of eBook formats, with Amazon's own library boasting over 1,391,000 eBooks for download as of May 2012 ("Kindle eBooks" 2010). The Kindle provides the ability to display anything that can be printed on paper, and does so on a medium that very closely resembles it in terms of look, portability and aspect ratio, while significantly reducing the bulk and waste associated with the paper alternative.



Amazons Kindle

Source: [http://g-ecx.images-amazon.com/images/G/01/kindle/tequila/dp/KT-slate-02-1g.\\_V139457036\\_.jpg](http://g-ecx.images-amazon.com/images/G/01/kindle/tequila/dp/KT-slate-02-1g._V139457036_.jpg)

Recently there has been a surge in another technology that has potential in reducing paper use. Tablet devices have been flourishing, promising ultra portable mobile computing to consumers. In addition to being able to read books and other documents, they offer web browsing, email access and a number of other features, while being smaller than a letter size note book, and weighing much less than a laptop. By far, the most popular tablet to date is Apple's iPad. It has taken the market by storm, selling over 7.5 million units over a period of seven months (Kellogg 2010). The device allows users to carry any paper they would normally carry in digital format. The iPad, which has a very versatile 9.7 inch display, allows users to easily download, edit, and share documents, read e-books in a multitude of formats, store most documents for easy views, and instantly access to anything on the internet. The iPad and other such tablet devices also offer the potential of running a host of other applications, limited only by one's imagination as is evidenced by the over 585,000 applications that are now available for the iPad ("Apple Launches New iPad" 2012). Such applications can manage data, edit documents, perform information processing tasks, and interface with proprietary software applications running on network or internet based servers.



Apple's iPad

Source:<http://www.apple.com/pr/products/ipad/ipad.html>

One of the reasons tablets have become so attractive, besides their convenience and affordable costs, is due to capacitive touch screen technology. The technology allows for the displays to detect multiple touch events by measuring changes in the screens electrostatic charge (Fenlon et al. 2007). The result is a highly sensitive and accurate touch screen allowing for effortless intuitive control. This hardware allows for software that provides users the ability to hand write on the tablet with a stylus as they would with a pencil or pen. Combined with a built-in, display-based or wirelessly connected physical keyboard, these tablets make annotating and editing any document as easy as it would be on paper or a computer.

#### *Current state of the art software*

While innovative devices hardware technology have opened up new vistas related to portability, human interface and data storage, software is the key for developing practical functionality for users. However, complex software requires great data processing capabilities, which have also become available in extremely compact and inexpensive processor chips. The Central Processing Unit of an iPad has greater processing capacity than a mainframe computer of the 1970's, which would have occupied a large room. Yet this miniature marvel costs a small fraction of one percent of the all the processor components of the old mainframe even in inflation adjusted dollars. This enormous raw computing power has made it possible for developers to write software that can deliver to the average consumer, capabilities that only 35 years ago would have been the subject of science fiction.

Documents that are printed on paper today are almost exclusively created on computers and other electronic devices by a slew of software, the most common being word processors, spreadsheet and presentation applications. The files generated by these applications are entirely suitable for distribution and editing. However, the great demand for marking a document by hand and while maintaining the integrity of the original document leads to printing the document on paper. Fortunately Adobe's Portable Document Format (PDF) tools provide the electronic equivalent of printing. Any printable document created by another application can be rendered in a static electronic file that can be displayed on a screen. Reader software written for most platforms allow PDF files to be displayed on almost any computing device and there are applications that permit overlay marking of these documents either using the keyboard or handwriting on touch screens and graphics tablets.

Though PDFs are excellent for digital documents, they can become inefficient for larger publications such as books. For this reason, there are a number of other formats the e-books, most of them compatible with each other. E-book formats allow the user to customize the text by changing both the style and size of the font. E-books also allow for the text be formatted to specific pages, making them easier to read on different devices and screens. E-books have been gaining momentum as they are easy to download and often cost less than their print counterparts. One notable source of e-books is a collection called Project Gutenberg. Project Gutenberg offers over 33,000 e-books for free. The titles offered no longer have copyrights making the distribution completely legal. Many books in Project Gutenberg's library are still relevant, and are used in classrooms around the world especially in literature. Another notable source of e-books - a front runner in digital publications, especially in education - is the company Zinio. Zinio provides digital formats of printed materials including periodicals and textbooks. It works with a variety of publishers to provide users the ability to purchase content once, and view it across multiple devices including personal computers, phones, iPads, and other iOS devices. An excellent example of where the eBook industry is heading can be seen in an application for the iPad called Inkling (<http://www.inkling.com>).



Fig. 2 User manipulating a 3D model of a DNA molecule in a biology textbook

Inkling provides interactive text books in multiple subject areas taking advantage of the technologies in the iPad. A video on the inkling best describes it as “[reinventing] the notion of a textbook from the ground up...[by] bringing together text, video and 3D objects” where the user can manipulate objects, broadcast notes, and be part of the book.

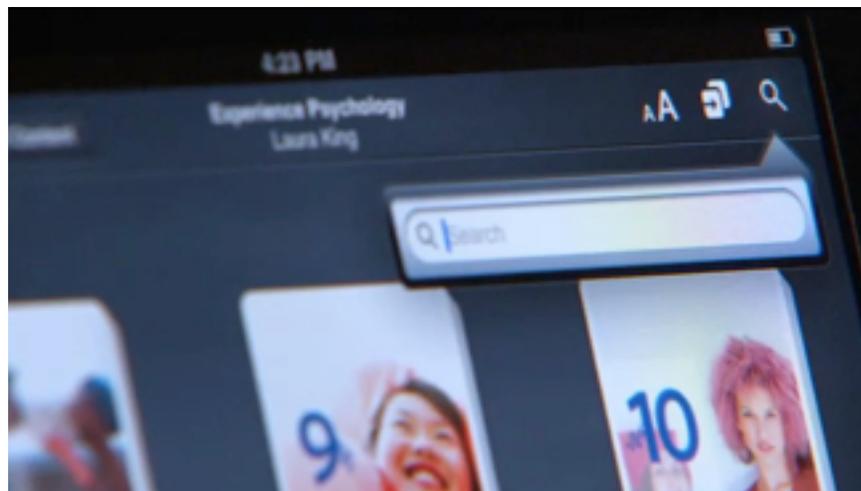


Fig. 3 Users have the ability to quickly search through an entire textbook.  
<http://d2z57atfnbxql8.cloudfront.net/www/media/video/inkling.mp4>

Inkling takes the content from textbooks, reorganizes and reformats it for the iPad, and embeds multimedia components into the pages, creating an immersive environment for the user. The application enhances the user experience, by providing an interactive learning environment in ways a paper book cannot.

E-books are definitely an important resource in going paperless. They successfully mimic books, are readily available, and are as easy to use as a regular book. One company is striving to propel them to the next level. Inkling is currently pioneering interactive text book on the iPad. Though content is currently limited, progress is being made on bringing a number of titles to the company. One title currently available, Biology by Raven et al, provides an excellent example for what is to come. The book is redesigned for the iPad's multitouch screen, while the content remains the same. Touching a reference in the text to a figure, table or definitions scrolls to the referenced material. When learning about different molecules, the user is able to bring up a 3D manipulatable model of the molecule. At the end of a chapter, when there is a review quiz, users can answer questions right on the page, and are given answers without having to flip to the back of the book ("Inkling Features - Interactive textbooks for iPad" 2012).

One example of a note taking application on the iPad is NoteTaker HD. It allows for a hybrid of hand written and typed notes, with tools to add pictures and graphics. It provides tools to optimize handwritten notes for the iPad like the zoom window and palm rest. The palm rest gives the user an area to place their hand that doesn't take any input. The zoom window allows for large, easier to produce, handwriting to be shrunk into equally readable, more space efficient writing. Left and right hand options make it easy for anyone to use unlike most notebooks.

Other note taking applications such as Evernote include additional tools such as audio capture that uses the mic to record what's being said while you take note. It also provides syncing with its cross platform versions of its app for desktops and smart phones.

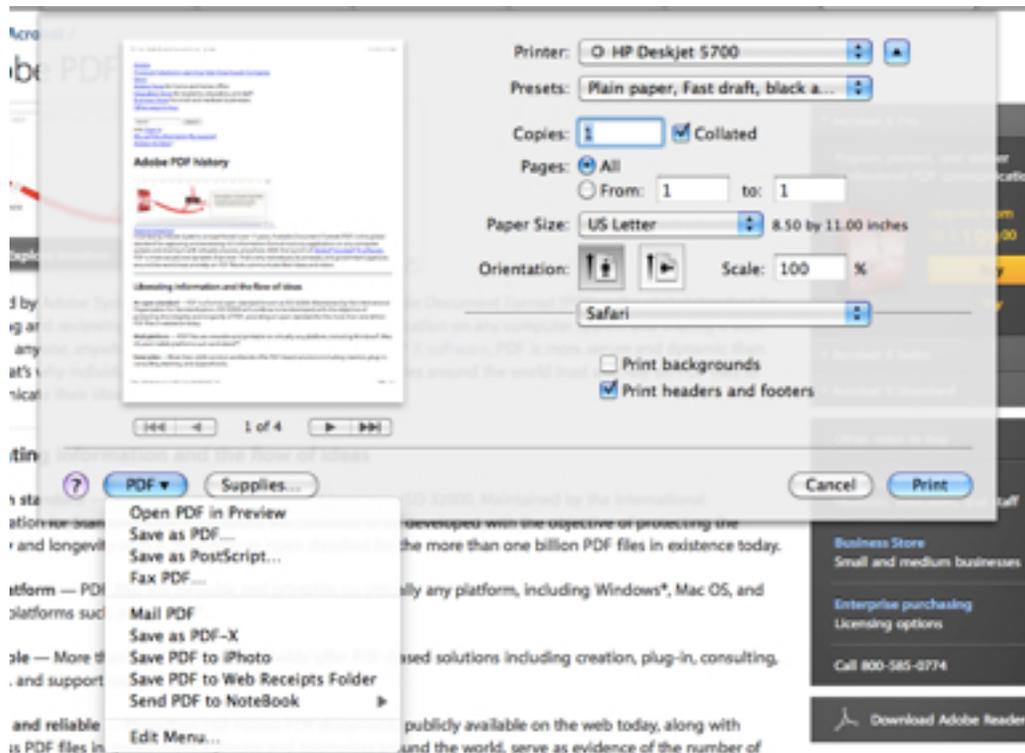


Fig 2. Mac OS X allows users to create PDF documents in the print menu.  
Source: Screenshot of print menu

The marriage of sophisticated software and advanced electronics has brought to us the ability to network computing devices. Over the past three decades the developments in this area have focused on speed of data transfer, security and universal access that is persistent. Wireless networking and cellular data connectivity has made it possible to provide all authorized users access to resources that are connected to the internet as long as users can connect directly to a closed network or the internet. The immense penetration of internet around the world thus enables instant interaction from far corners of the globe. The continuing increase in the speed with which data can be moved on this global network permits us to achieve increasingly practical access to information, irrespective of where it resides.

The benefit of centrally stored data is obvious in collaboration and multi-platform processing. However, using remote data certainly slows down processing, so solutions have been developed to synchronize copies of the data amongst different devices or storage locations. This then also permits offline working when instantaneous sharing of data with others is not required. The low cost of storage media, networking bandwidth, and techniques for incremental replication makes this entirely practical. Standardized protocols and multi-platform software for this make it possible for a diverse set of devices to synchronize information amongst themselves. One such application is WebDAV, which among other things enables one to synchronize the contents of data folders residing on a variety of devices, ranging from servers and network storage to personal computers and hand-held devices.

## 2.5 Case Studies

Going paperless has many advantages that vary from situation to situation. In education, the paperless classroom has its advantages as seen in Hartwick College's Department of Business Administration and Accounting. Priscilla Z. Wightman, associate professor and chair of the department, replaced pen and paper in the classroom with laptops in 2004. She believes that going paperless helps both the environment and in teaching student valuable skills for their future careers. Her experiences indicate that there is a learning curve to going paperless, for her, five years, to get truly comfortable with reading, grading, and managing all of her papers online (Fontelera 2010).

Wightman has built going paperless into her curriculum, phasing students into the mindset while teaching them helpful hints such as file naming conventions. Going paperless also allows for students to integrate online resources such as the most up to date stock prices in problems. Another resource available is accounting e-books with practice problems that offer instant feedback (Fontelera 2010).

Businesses also have a lot to gain from going paperless. International Business Machines Corporation (IBM) has recently shown initiative in reducing paper use. Ken Bisconti, a Vice President at IBM heads up the department that handles Enterprise Content Management which refers to "the management of unstructured content, which comprises about 80% of the world's business information today. It's everything from email, and scanned documents, to Compound Document Management, and now archiving content analytics, records management, even case management, business processes." In an interview with blogger Tom Raftery from GreenMonk, Bisconti talked about paper use, and its reduction, in the cooperate world. Bisconti notes that most of the paper used is for business communications, transactions, and legal documents that require a signature (Bisconti 2010).

Bisconti believes that "due to the decreased cost of digital storage and improvements in technology, ... it is much more cost effective now to take advantage of digital capture," especially given how much easier it is to store and retrieve digital work than information recorded on paper. Throughout the interview Bisconti emphasized the monetary savings associated with going paperless. He also highlighted digital security and disaster recovery as additional benefits.. Through the use of digital encryption, users can prevent unauthorized users from viewing data, and by backing up data offsite, users can recover data if their primary storage is compromised (Bisconti 2010).

## **2.6 Summary**

Section 2 gave a brief overview of paper, examining its life cycle from production to disposal in order to better understand the environmental impacts of paper. Next, paper was evaluated in regards to its role in education. This identified the characteristics and benefits of paper that give it such a prominent role in education and that would have to be replicated in order to effectively replace paper. Finally, the section looked at the history and assessed current products and technologies that have an impact on paper consumption and reduction. The next section will go over a survey that was designed and conducted to provide insight into the current paper practices of WPI students.

## Chapter 3: Data Collection

### 3.1 Introduction

This section begins by looking at a survey sent out to students that was designed to better understand their paper practices at WPI and their experiences with eBooks. The section explains the methodology used to create and distribute the survey, and then highlights some of the results gleaned from the raw data and provides a brief analysis of the results. The section then goes on to summarize data gained from interviewing WPI faculty on their thoughts and practices in regards to paper reduction in the class room.

### 3.2 Student Survey

A survey, designed to better understand student paper practices at WPI, was sent out to students to learn about their experiences with eBooks. Presented below is the methodology used to create and distribute the survey, highlights of the resulting raw data, and a brief analysis of the results.

#### *Methodology*

To better understand paper usage practices at WPI, students were surveyed on their personal habits. A 15 question electronic survey, as seen in appendix 1, was created and emailed out to WPI's student body. The questions were designed to understand students' thoughts on and experiences with replacing paper with other technologies. Of the roughly 3,500 students the survey was sent to, 354 responded, a response of about 10 percent. The survey was designed to find out how much paper students use, and what happens to the paper they are given. We also wanted to find out students' experiences and preferences on using eBooks instead of textbooks.

The results indicate the sample population has diverse practices when it comes to paper consumption and preferences. Students were asked questions about how much paper they printed, what they did with hard copy handouts, and their preferences. In an attempt to streamline the data, making it easier to analyze, most of the questions on the survey were multiple choice. Students who indicated they had used eBooks before were requested to evaluate their experience with them, and provide additional comments on the pros and cons associated with using eBooks.

## Results

The first question, “On average, how many sheets of paper do you think you print out per term?” had a majority of students reporting that they printed less than 70 pages a term. Their responses can be seen in the chart in fig.3.

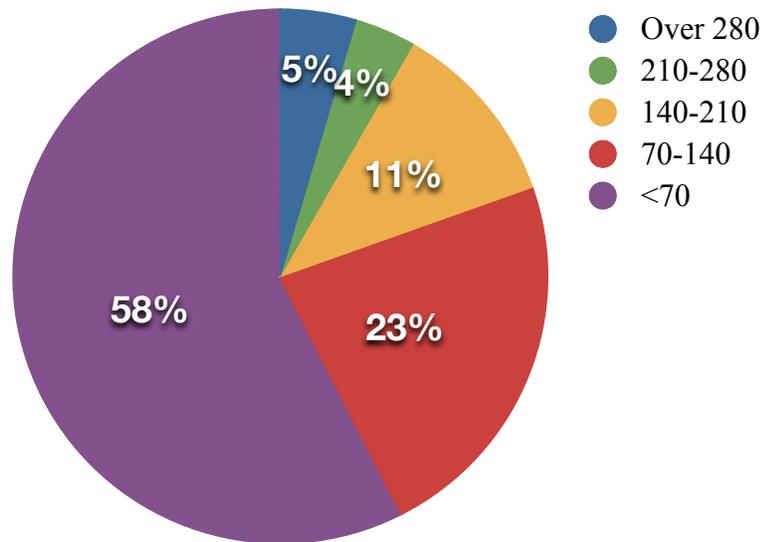


Fig 3. Responses of students when asked how many pages they print out a term.

The second question, which asked students where they printed, indicated that 55% of students print using university printers. When it comes to double sided printing, 52% of students surveyed indicated they did use double sided printing, with the remainder either not thinking to, or not knowing how to print double sided. Results are shown in the chart in Fig.4.

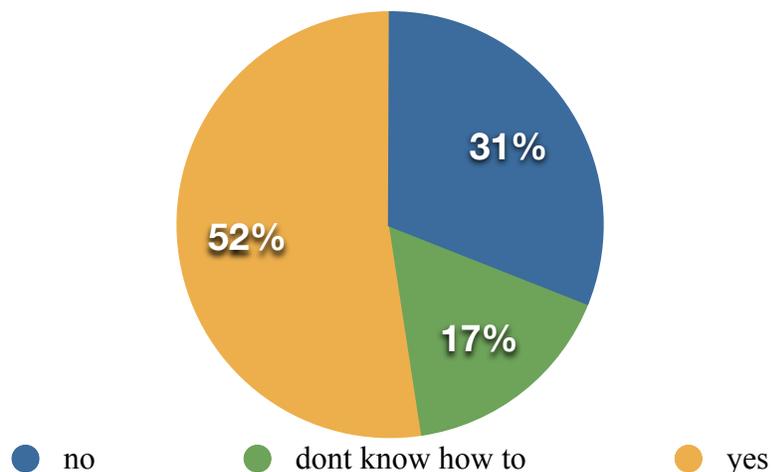


Fig 4. Responses of students when asked if they print double sided when not required to do otherwise.

To learn more about students’ experiences and preferences with eBooks, we looked at the 116 students that indicated they had used eBooks previously. Most had positive feedback on them with 90% saying they would use eBooks again, including 30% who would like to see all their textbooks in the format. Some of the biggest pros using eBooks cited by the respondents

include the cost, search-ability, portability, and accessibility. To read the eBooks, 78% of students exclusively use a computer. Those who use a tablet or dedicated reading device were more likely to have a good experience with the eBooks, with all of them saying they would use eBooks again. Most of the cons reported with using the eBooks were associated with conditional software limitations such as highlighting text, annotating and requiring an internet connection to use them. One situational con that was brought up multiple times was the inability to use eBooks on open note exams. One physical con that was reported by some respondents was eye strain, a problem usually associated with bright backlit LCD screens.

Another question the students were asked was whether they owned a portable device capable of reading eBooks. If they did, they were asked to specify a brand. The results shown in table 1. show that 99% of students already have the necessary hardware to use eBooks.

Device	% of student that own one
iPad	11.61
Laptop	97.17
Kindle	10.20
Android Tablet	4.53
other	7.37
none	1.13

Table 1. Percentage of students that own a portable device capable of reading eBooks by device type.

### *Analysis*

There are a lot of students who are using more paper than they need to. With the number of students using university printers, WPI can have a direct impact on students' paper consumption. By reminding and instructing users to print double sided, or making double sided printing the default option, a significant fraction of paper usage could be cut out. Paper could also be reduced by creating policies for the use of eBooks on open book exam, and by adding the resources to download eBooks to course syllabi.

### **3.3 Faculty Interviews**

Faculty members from different disciplines, teaching different type of courses, were interviewed to better understand their perspective on paper reduction technologies and solutions being implemented in the classroom.

#### *Professor Rudolph*

Professor Rudolph is a professor of Humanities WPI. She teaches a variety of courses at different levels including inquiry seminars, which focus on producing a culminating research paper. Depending on the course level, class sizes range from 12 to 50 students.

Prof. Rudolph recently stopped distributing hard copies of all course materials to students, opting instead to post all materials on myWPI, for students to download at their convenience. In

addition to standard handouts, she takes advantage of the platform to distribute video and other multimedia content applicable to the course.

When she stopped distributing hard copies of course materials, Rudolph also stopped returning hard copies of student papers. Originally students were able to turn in papers either hard copy or electronically, but a hard copy would always be returned with comments and a grade. Now Rudolph requires all papers to be submitted electronically. When she reviews them, she has a rubric open next to the paper, and she fills it out with grading information and comments. She still prints out the one page rubric, but it a sizable reduction over the average 5 page paper. An exception to this practice is requiring students in her inquiry seminars to submit their final papers in both digital and hard copy. This is due to the Humanities and Art Department which requires a hard copy of each students' final inquiry seminar paper.

For each lesson, Rudolph takes a hard copy of all the materials related to the lesson. She tries to save printouts for when she teaches the course in the future, but since it can be up to 2 years the course is offered again, the copies sometimes get misplaced and are reprinted.

Rudolph sometimes prints out emails and documents to read away from her computer. Most of these printouts are intended to be read once, and often end up in the recycling bin by the end of the day.

Rudolph says that she is interested in using a tablet to reduce paper usage, but admits to knowing very little about the capabilities of the technology. She expressed great interest in learning how to use the technology in the classroom, but was concerned about the personal cost of purchasing the technology. She is a lot more inclined to use a tablet device if the university provided the hardware and training to go with it.

Prof. Rudolph is prime example of someone who has taken the initiative to reduce paper use in the classroom, but is unaware of technologies available to further that goal.

### *Professor Keil*

Professor Keil is a professor of Physics at WPI. Keil primarily teaches the introduction to physics course which sees about 600 students per year. Keil estimates that he prints out about 80 pages of paper for each student. Printouts consist of exams, homework assignments, lecture notes, and lab reports. All documents that are printed out have electronic copies accessible to students, except for the annotated and graded lab reports.

Before each class, copies of the lecture notes and home works are printed out for each student a placed outside the lecture hall. Students are free to pick them up if they want them. The remaining copies are kept in the physics office for students to pick up later. Professor Keil is “a fan of going paperless where it makes sense,” and prints out everything for the students because he students who want the hard copies do not have to cover the printing costs.

Lab reports are created and submitted electronically by students. Electronic grading proved to be difficult when it came to annotating and efficiently returning the assignments through myWPI. Keil and the TAs therefore opted to print out the reports for grading. Keil however was quick to note that if there was a better system to organize, annotate, and return the assignments, he would be in favor of using it.

### *Professor Padir*

Professor Padir is a faculty member of WPI's robotics department. He primarily teaches courses in the unified robotics series. His average class has between 30 and 35 students. Padir only prints out the course exams for his students, and makes all other materials available online. He estimates that the exams come to a total of about 25 pages per student. Professor Padir puts all his class notes, homework and lab assignments, and supporting documentation online for students to access.

Lab assignments for Padir's class are written up electronically, and submitted to him through myWPI or email. He then grades and annotates them electronically before emailing the graded report back to his students. In the beginning, Padir found it inconvenient to do everything electronically. "At first it seems to be a big step, and it takes a while," but after getting used to it, doing everything electronically became just as easy as using paper. What helped Padir was standardizing submission formats. By making sure that all documents came in as a PDF or word document there were no compatibility problems.

One area that Professor Padir noticed used a lot of excess paper was note on his open note exams. Students in Padir's class usually print out all of his class notes he posts online specifically to use during the exam, only to be discarded after it. When asked about allowing students to be able to use electronic devices for notes, he was not against it, but had concerns about students who didn't have a tablet or laptop being at a disadvantage. He also expressed concerns about potential issues that having an internet connected device had to academic honesty.

## **3.4 Summary**

Section 3 looked at a survey created for and distributed to WPI students, and interviews with members of WPI's faculty. The results, which represented a cross-section of 10 percent of the students, expose the wasteful nature of paper use amongst WPI students, particularly when it comes to printing on university computers. The results also showed the pros and cons identified by the students', mostly positive, experiences with ebooks. The faculty interviews provided insights into paper reduction practices currently employed in some class rooms, and highlighted areas in which paper use can be further reduced. The next section provides some solutions to reduce paper usage at WPI in the future.

## Chapter 4: The Way Forward

### 4.1 Introduction

This section provides solutions aimed at reducing the paper consumption at WPI. Solutions range from the simple, such as setting two-sided printing as the default option on university printers, to more complex suggestions that will require a long term plan to implement.

### 4.2 Paper Reduction Solutions

To reduce the consumption of paper at WPI, the university must not only use paper more economically, but must also employ alternative methods and mediums to replace paper in activities and processes that, until now, have relied on it exclusively. Much of the former is achieved in present circumstances by simply implementing practices to ensure duplex printing and copying.

The latter solution asks us to be more creative. In order to find a viable alternative to paper, one must identify an alternative that is both convenient for the community and is not simply as attractive as paper, but is more attractive than paper. The more attractive the alternative is, the more willing the students will be to invest in devices that make a paperless existence possible.

#### *I. Textbooks*

In the typical classroom, textbooks heavily contribute to the use of paper per student. One cannot deny the importance of a textbook, however, it is possible to debate the necessity that it be printed on paper. Earlier sections have put forward several online or electronic alternatives to the printed standard. Of course, eBooks and tablets come with a unique set of challenges. For instance, there would need to be restrictions on what sorts of tablets could be used in different situations. A teacher could hardly be expected to allow iPads into an open-book exam setting. With their capacity to surf the web, there would be little stopping students from meandering outside the boundaries of their textbooks. That being said, this issue is not insurmountable. Between the honor system and enforceable restrictions, it is possible to account for special circumstances such as these. Needless to say, the benefits of paperless textbooks far outweighs the narrow set of consequences that accompany the change.

#### *II. Handouts and other materials distributed in class*

Another substantial component of printed information is readings and other information such as course syllabi that are often printed by professors and distributed to the students in their courses. This must be all be made available in electronic form from an online platform. When the professor places a document on the online platform for a course, the students enrolled in that

course must be automatically notified about the new course material with a link to the particular file. Students can then read this information online or download it to their computing device of choice. Printable documents, in this context must be distributed in a PDF format for cross-platform acceptance as well as the annotation capabilities then available to the recipient.

This material is to be made available to students on the multiple personal devices that they may use, such as computers, tablets or smartphones, equipped with an application that enables course-wise organization of the various documents that are downloaded by the student. This can be achieved by providing each student with personal online storage on the WPI network which will serve as the authoritative copy of all their retained documents which each of their personal devices will synchronize content with. This way, annotations and modifications made by the student to their personal copy of any document on any device is replicated across to their multiple working platforms. This will provide data security, complete portability and the means to incorporate personal notes on information received.

### *III. Assignments*

To fulfill course requirements and complete work assignments from the professor, students will generate documents on the various computing devices they use. These would then be added to the information store of the documents distributed to them by professors. As a result, these students' personal documents and assignments fall into the networked personal information store replicated across their various devices via the synchronization with their personal storage on the WPI computing infrastructure.

With this arrangement, students will be able to electronic submit their work. Professors will be able to set requirements and deadlines as needed. If the PDF format was set as the standard, professors would then be able to access all the student submissions online via a tablet device, download them for offline work, annotate the submissions as necessary, record a grade for the work, and then synchronize the resultant files back to the network based receiving folder. The professor may then initiate an electronic redistribution of the graded documents back to the original student senders with a single command.

### *IV. Personal Notes*

With this core capability in place, and armed with a tablet device students will automatically have the ability to attend lectures, tutorials and labs and take hand written notes, typewritten notes, photographs, audio or video recordings. They can place the resultant files in their composite WPI information store which then will be available to them on each one of their devices as needed and protected from loss by the reliability and archiving practices of the WPI data network infrastructure and services. It is of course easy to imagine potential abuse of these facilities, particularly if students are not discerning about the nature and quantity of material that

they store. To counter this, the institute could establish a base storage quota available free to each student and make available additional storage at a reasonable cost.

### **4.3 Implementing the Solution**

Having laid out the functionality of the proposed move to an operation that consumes dramatically less paper, we look at how specifically this can and should be implemented. Interestingly, WPI already has in place some of the technology and tools that are required. However, what is available does not in any way lead to paper reduction; in fact, it may well be responsible for increased paper use in the same way that personal computers and modern printers caused the paper explosion. This, of course, is largely due to the fact that appropriate technology was not available earlier, and so information processing initiatives for the WPI community were focused on managing information and its flow without any regard to the quantum or nature of paper use it generated.

#### *I. myWPI*

myWPI currently provides professors with the ability to make all types of informational and instructional documents available to students. However, the students must themselves access this information, download it and manage its storage on the devices on which they will use it. At the same time WPI also provides each student a modest amount of data storage capacity on its servers but how that is used and accessed by students' computing devices is left to the ingenuity of the individual. While there is nothing wrong with that, it does not produce any uniform effect for reducing paper usage.

The proposed functional solution requires that these two core services of the WPI education information processing infrastructure be upgraded to provide the desired functionality explained earlier. In addition, cross platform applications need to be developed, one for students to install on their various devices--that will permit them to synchronize their personal information stores across devices with their personal storage space on the WPI network--and one for the professors' tablet devices--that will permit professors to download and synchronize PDF document content with folders within the myWPI application. Commonly available PDF software on such devices, like Evernote for the iPad, will permit them to annotate and mark up these PDF documents.

myWPI permits professors to upload documents to course folders and then permits students identified as enrolled for the course to read and download these documents. The enhancement for automatic notification calls for myWPI to email to each enrolled student a link to each new document posted into the course folder. This could be achieved by a server resident service that would monitor course folders. Each time the server resident service detected new

additions, it would trigger an email dispatch, containing the location of the new file, to all the students linked to the relevant course folder.

### *II. Add-on Something*

The myWPI application also permits electronic submission of assignments by students. However, this functionality currently hardly eliminates any paper use as most professors request paper submissions. Even those who accept electronic submissions generally print the submissions to facilitate grading and return of the graded work to the students. To have a truly paper-free process the capabilities of myWPI need to be augmented by a separate complimentary application.

myWPI provides a satisfactory interface and process by which students can submit their work into myWPI's structure. The add-on application requires two components. The first would be designed to allow professors to download student submissions and extract the PDF documents from corresponding zip files. This same component would place those PDF files in a special purpose folder for the course that would be tablet-accessible through the use of WebDAV technology. Professors would then use their tablet devices with available PDF software to review the submitted PDF files, annotate them with their grading remarks, and save them back in the same WebDAV folder. WebDAV technology also automatically makes it possible for a local copy of the file to be available on the tablet device, enabling offline work. This then provides full portability and mark up capabilities that professors desire when grading students' assignment submissions.

After the grading is completed, the second component of the myWPI add-on will enable the Professor to move the graded and marked up student PDF files back to the myWPI database, replacing the original submissions. These will thus become available to the students when they log onto myWPI.

The wide range of APIs available for integrating Blackboard with other applications make this enhancement of myWPI a manageable task.

### *III. Exams*

Considering the degree to which examination formats can vary, and the ease with which students would be able to unfairly access additional resources on tablet devices, it might not be feasible to eliminate paper for tests and exams. Luckily, exams tend not to use as much paper as paper assignments and textbooks, as they are administered less frequently.

### *IV. Printers*

Finally, to address reduction of paper consumption where printing cannot be avoided, all printers on the campus should be configured to deliver two sided output as the default. Administrators would have to make sure all users have two-sided print on in the default preset

for all departmental and library printers. Older printers that do not have auto-duplex capability should be replaced with units that are so capable, as and when the old units are phased out. This would ensure that anyone who prints a multiple page document will get it printed double sided by default, without needing to adjust any settings.

#### **4.4 Summary**

Section 4 provided solutions to reducing paper at WPI. The solution to integrate tablets into the school's curriculum would greatly reduce the need for paper, and leverage many of the advantages of paperless technologies to enhance learning. Though the costs, both monetary and time, to implement the solutions seem high, the results would justify the costs.

# Appendix 1: Student Survey

## Paper reduction survey

The purpose of this survey is to get a better understanding of paper usage and practices of students. The data gathered will be anonymous, and will be used to determine how to practically reduce paper usage at WPI.

### 1) On average, how many sheets of paper do you think you print out per term?

average HW - 3 pages, average lab report - 5 pages, average writing assignment - 8 pages

- Less than 70 sheets (10 pages a week)
- 70-140 sheets (10-20 pages a week)
- 140-210 sheets (20-30 pages a week)
- 210-280 sheets (30-40 pages a week)
- Over 280 sheets (40 pages a week)

### 2) In your courses, when it comes to lecture notes, formula sheets, syllabi and other handouts, do you prefer?

- Paper copies available in class in addition to being available online
- Being available only online to be printed at your discretion
- Both

### 3) If you receive a hard copy of class notes, that is also available online, what do you do with them?

- Glance over briefly then discard or loose them.
- Keep them and review them until the next exam/end of term.
- Keep it to be used as a reference for potential reference in a future class.
- Ignore it completely and just use the online version.
- No hard copy handed out in class, only online versions available.

### 4) When printing documents for school, where do you print?

- My own printer
- A friend's printer
- Departmental printers (ECE, ME, RBE, etc.) because I get free printing each month
- Library printers

### 5) Do you use double sided printing

- No. Doesn't occur to me.
- No. I don't know how to.

- Yes. Whenever I'm not required to print single sided.

**6) HW and lab reports that are returned after being graded are**

- Valuable. They are reviewed and kept.  
 Worthless. They are discarded/recycled almost immediately.  
 Valuable, but I would prefer that everything be done electronically so that I could easily reference the material.

**7) When do you take notes in class?**

- Never.  
 Only when the lectures are NOT posted online (lecture capture, professor's notes, etc.)  
 Always, to supplement any note the professor may post.

**7a) If you take notes, how do you take them?**

- On paper. In a notebook or binder.  
 Electronically. Either on a laptop, iPad, tablet, ePaper, etc.

**8) Do you own any of the following devices**

- Laptop  
 iPad  
 Kindle  
 Android Tablet  
 Other dedicated digital reading device

**Have you ever used an eBook for a class?**

- No  
 Yes

**eBooks**

**Which courses have you used an eBook for?**

**How was your experience with eBooks?**

- Great. I wish all my books were in this format?  
 It was alright. Wouldnt mind using them for certain courses, but not all.  
 Terrible. I will only stick to hard copies.

**What device(s) did you use to read your device on?**

- laptop
- iPad
- Kindle
- Android Tablet
- Other dedicated digital reading device

**What were the pros of using an eBook?**

**What were the cons of using an eBook?**

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