Electronic versus paper record keeping in scientific research: a case study for the Open Exeter[1] project

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1 Overview

In this case study the nature of record keeping for two different kinds of research in Physics, experiment and theory, is used to assess the potential value of keeping electronic instead of paper records. We find that, although there is already a range of positive aspects to electronic record keeping, the software currently available is not yet able to fulfill all of the requirements of a lab book and may be inappropriate in novel working environments. Given the rate at which the relevant hardware and software is developing and the option for researchers to try current note taking software for free, we suggest waiting at least another year and assessing the latest options before investing in support for electronic record keeping.

2 Introduction: The importance of lab books

The importance of note taking in research is stressed from the first weeks of undergraduate study (if not earlier). On one level research notes act to remind the researcher what has been done in the past. This helps to negate the repetition of flawed ideas and also helps when it comes to producing a journal-quality article or thesis based on the work.

Potentially more importantly, science is a pursuit based on the ideal of reproducibility. Modern research is sufficiently complex that a given theoretical calculation or experiment may be difficult to reproduce exactly from journal details. Lab books and associated notes are therefore an important accompaniment and need to be retained should the research ever be attacked and require re-validation. Records can also play an important role when the credit for a discovery is disputed, providing a difficult–to–falsify record of the research leading to the discovery over a significant period of time. Finally, lab books provide valuable evidence if a grant holder is audited.

Given the above, what does a 'traditional' pen and paper lab book comprise? Ideally the following:

- A hard bound book (as opposed to something like ring bound where old records can be removed without trace).
- Frequent entries. Dated, with pages numbered and no large white space (e.g. one third to one half of a page is a large amount of white space). This means that the fabrication of entries would be very difficult.
- No loose papers. Figures should all be secured in the lab book. Loose entries weaken the power of the lab book to act as evidence that a recorded piece of work was performed at a given date.
- Notes should be detailed enough so that someone who is unfamiliar with the project

[1] http://as.exeter.ac.uk/library/resources/openaccess/openexeter/

can reproduce it in full.
- Eventually, a contents page to assist in navigation. This is sometimes complex in practice given the non-linear nature of research.

There are two running themes in the above with regard to record keeping: one is the storage of information on the research and the other is proof that the research progressed in a certain way at a given time.

Traditionally, electronic lab books have been discouraged because they can be edited more discreetly at future dates. It has also been more difficult to make notes in real time (as you are turning the dials on your experiment) with a computer as opposed to a lab book. However, recent advances in computer technology may make electronic record keeping more realistic. The ability to record notes in a synchronised fashion across computers, tablets and phones in formats such as pictures, text and audio is making electronic note taking a more realistic prospect than ever before. Furthermore, if version control is automatically enforced then electronic record keeping could provide even more robust evidence for the state of work at a given time than hard copies.

We are now entering an age where scientific research materials are becoming more readily available than ever. Initiatives such as the Open Research Exeter (ORE) repository allow the public to access research data. This is in concordance with recent legislation under which publicly-funded research data has to be made freely accessible. In addition to fulfilling the traditional lab book roles, a transition to electronic format may further advance this public availability of research data. However, this will clearly require caution regarding the interests of the researcher prior to the publication of any journal article based on the records.

This report looks to investigate the relative merits of electronic and hard copy record keeping. Would it be valuable to migrate more formally to electronic lab books? What would be the requirements? Based on the requirements of the authors in their record keeping, trial use of electronic note taking software and discussions with colleagues we address these questions. The rest of this report proceeds as follows. In section 3 the background work of the authors is introduced. We then summarise our respective record keeping behaviour and requirements in sections 4 and 5. Using this, we discuss the practical implications of moving to electronic lab books in sections 6, 7 and 8 and provide overall recommendations in section 9.

3 The authors

Thomas Haworth is an STFC-funded third year Astrophysics PhD student at the University of Exeter working on numerical simulations in the context of star formation. His work primarily comprises code development and the running of large calculations on supercomputing machines. These calculations investigate the interplay between the hydrodynamic evolution of star forming regions and radiation from young stars. Simulated observations are also used to compare the calculations with real telescope observations of star forming regions.

David Hudson is an EPSRC-funded third year Physics PhD student at the University of Exeter investigating the various charge transfer mechanisms at the interface between a superconducting metal and graphene. State of the art nano-fabrication techniques are used to create electronic devices and these are measured at low temperatures to probe the quantum behaviour of the materials.

4 Record keeping in Experimental Physics - David Hudson

In Experimental Physics the role of the lab book is primarily to keep an organised list of when and how a measurement is performed. It may also contain instructions on how to use equipment, sample fabrication methods, calculations and printouts of data. The advantage of pen and paper for this kind of work is the portability of a book and the speed at which information can be transcribed to the page. When learning how to use a piece of equipment short hand notes and sketches can be drawn while someone else is instructing; this would be hard to replicate digitally without a stylus. When fabricating a device for measurement all of the details can be jotted down at the various points in the sample's lifetime. This information would be much better stored digitally as you can amass a large catalogue of devices and so it can become cumbersome to check back the individual details of each device. When measuring a device; the date; the exact details of the equipment setup and the locations of the data on the computer are recorded in a list in the lab book. This list is referred back to later when the data is to be analysed and would be difficult to work without it. Calculations for circuit setup and analysis are almost always best done by hand as this is much more efficient than using an equation editor on the computer. Contrary to this almost all data processing is performed in a specialised software package on the computer. The results of this analysis will probably not be entered into the lab book as it would require printing, cutting and sticking, and it is generally considered bad practice to insert material into lab books. In this case a digital lab book would be useful as it could be used to plan out the journal paper linking the measurements, results and analysis into the same place.

With this information in mind my requirements for a digital lab book are as follows:

- Portability (size and weight similar to that of a book).
- Stylus input method.
- Software which can link typed text, hand written text, drawings, raw data and plots.
- Easy and efficient to use (approaching the ease of writing in a book).

5 Record keeping in Computational Astrophysics - Thomas Haworth

I keep separate lab books for each project that I undertake. This averts confusion when I am working on multiple projects at once and also means that each lab book follows a more logical progression. The vast majority of the notes that I add are small updates on progress. An example of this kind of entry is given in Figure 1 (Figures are included in Appendix C, page 13). Typically, once I know that a task needs to be done I write a reasonably lengthy description of it. An example of such an entry is given in Figure 2. Where required, the lab book takes on a rough work role rather than record keeping. For example, when I am deriving equations or trying to piece together an idea. Pen and paper is perfect for this kind of work where I need to be able to jot down and play with equations/diagrams. An example of rough work with equations and figures is given in Figures 3 and 4.

Figures and computer code segments are also included in the lab book at times. However, this requires printing/cutting/sticking them in to the lab book. As a consequence I probably include less of these than I otherwise should. I find that at a research level the entries in a lab book are sufficiently disordered that it is very difficult to include a meaningful contents page. For example, components of a particular part of the project may be interspersed with other parts. This makes navigation of the lab book very difficult for anyone other than myself. I also find that regular entries are not always feasible, for example, while waiting for calculations to run on the supercomputer. Typically, if a calculation is running and the method of analysis of the results is clear and well documented in my lab book I will not have anything further to add for a while. In this period I usually work on drafting the related journal article and entries in my lab book are relatively sparse.

5.1 My electronic record keeping requirements

Ideally when it comes to electronic record keeping I would want to retain the ease with which I can work with equations and diagrams, but also to improve the ease with which I store figures and code fragments. I would want a notebook with entries for each day, like a calendar, that could also be sorted by entry topic (for example a keyword) rather than by date only. This would vastly improve the 'contents page' problem, allowing a reader to view the entries both by date and by subject. I would also require separate electronic logs for each project that I am undertaking. It would be crucial to be able to access the electronic logs through as many hardware platforms as possible – phone, tablet and computer would be essential.

The obstacle regarding the inclusion of written equations and pen diagrams could be solved by uploading photographs of paper working. I have already successfully done this with Evernote using photographs taken via mobile phone.

6 Digital log keeping in practice

6.1 Methods of digital log keeping

The two main routes to producing a digital lab book would be to either digitise an existing handwritten lab book or to use an entirely digital system. As the University currently has no system in place it makes sense to first discuss the options that affect existing students and their handwritten lab books.

Digitising handwritten work

Pages from the lab book can be digitised by photography or by using a scanner. Both of these methods are straightforward and relatively inexpensive but can be time consuming. If the lab book is digitised only at the end of the PhD then it will be a laborious task to scan every page. There are several disadvantages to this method, especially when considering the purpose is to share the lab book with other people. Firstly, each page will have a file size of around 2MB; if a lab book has around one hundred pages and a student completes 3 or 4 lab books during their PhD then file sizes will become quite large. If the lab book is going to be stored permanently by the University then keeping the file sizes down would be important. A more pressing issue is the ability to search the lab book for useful information. Contents pages are usually an afterthought in a lab book; they may only highlight key pages. If the user has to scroll through hundreds of pages to find a small bit of information they are likely to give up. Optical character recognition (OCR) software is used to convert printed text into digital text and works fairly well, however, OCR software that can detect handwriting is not as reliable. This means that even though the lab book is digitised it may be fairly useless for anyone else who wants to read it.

Note keeping software packages

Nearly all scientific research is dependent on a computer for measurement and/or analysis of data, especially within the theoretical disciplines. This means that a large portion of the information that is presented in a journal article may not appear in a lab book at all. By using a software package on a computer to act as a lab book data can be collated alongside information about the experiment and the analysis. The flow from experiment to conclusion can be collected in one location. This could simplify things greatly when it comes to writing up a paper or reviewing at a later date. There are many different software packages available, some can be installed on multiple types of device (laptop, tablet, phone) and allow data to be synchronised between them. A brief review of a few different software packages is given in appendix A. They largely contain the same features, such as the creation of 'notes' that allow the user to add text, images and data files in an organised fashion. It is easy to see how this could facilitate searching and sharing of data. Notes can be titled and tagged with relevant keywords so that they are easily searchable. Individual notes or entire notebooks can be shared with other users of the program or can be exported to be sent via e-mail, for instance. The only disadvantage of these packages is that in general they are not tailored for exclusive use as a digital lab book; the ability to edit digital entries and possible forgery are issues that these 'general use' packages do not take into account. These ideas will be discussed later in section 6.

Tablet computer as a lab book

A tablet computer would be the ideal replacement for a handwritten lab book but it is by far the most expensive solution. The main advantage of the tablet compared with a traditional computer is that if a stylus is provided then sketches and fast notes can be added to the lab book. The tablet is compact and mobile enough that it could be taken to the measurement setups making it useful for real time additions to the lab book. A tablet might also offer the ability to monitor experiments remotely or even control aspects of them. If the right tablet and software is chosen then it could even be used to analyse the data as well, so the choice of tablet could impact its potential value to the student. An Apple iPad offers a highly polished and user friendly interface at the expense of a very closed/restrictive system. Managing files is difficult without a 3rd party app and this limits the potential for storing large amounts of data along with the lab book entries. However, being the most popular tablet on the market means that there are a large number of professionally produced note taking applications available. The iPad would be a good choice for a basic digital lab book but may not offer functionality beyond this. In the near future a range of Windows 8 (pro edition) based tablets would offer the full functionality of a desktop machine when plugged into a keyboard mouse and monitor alongside all the benefits of a tablet when unplugged. The advantage of using a Windows 8 based tablet over an Android or Apple tablet is the vast library of scientific software already available for Windows such as MATLAB and LabVIEW. These programs are extensively used throughout the Physics Department. The obvious disadvantage of using a tablet as a digital lab book is the cost per unit, with iPads starting at £269.

6.2 Persistence and integrity of electronic data

Data storage and backup

Data corruption or accidental loss of data can strike a digital system at any time and often for an unexpected or unforeseeable reason. Whether it be an internal or mechanical failure of a hard drive or accidental damage such as dropping the device, the result is the same, an unhappy student who has lost weeks or months worth of work. It is essential, then, that all records kept in a digital lab book are backed up to an external storage medium. There are a number of possible routes that could be chosen to back up the data but each method has various considerations that need to be addressed.

Network addressed storage (NAS)

NAS is simply a hard disk drive that would be accessible via the University intranet. A system like this is already in use by the Quantum Systems and Nano-materials Group in the Physics Building. Each member of the group has access to all of the data on the drive which is protected by a password. A system like this is relatively inexpensive with solutions starting from around £100. The main problem with such a system is that it is up to the user how often they make copies of their data as they have to manually add the relevant data to the system. For a digital lab book which would be written in daily it would be a laborious task to make sure the backup is up to date. The NAS drive is much better suited for the persistent storage of data taken in measurements and for weekly/monthly backups.

Cloud Backup

The prevalence of cloud computing has risen enormously since the availability of high- speed broadband services. Cloud computing is the use of a computer's resources that have been accessed over a network. For example, this could be the access and storage of data to a service on the Internet. There are myriad storage providers and the University itself provides online storage to each of its students. While it is good practice to backup data in more than one place the University's online storage also requires the user to manually upload files. Many free online services such as Dropbox provide automatic synchronisation of the data on the user's device by uploading it to their servers when a change is made to the file. This would be perfect for backing up a digital lab book as many pieces of software integrate Dropbox functionality into their programs. The concerns with using an online storage provider centre on the integrity and stability of the company that hosts the data. There have been many cases recently where the security of a user's personal information, such as passwords or email addresses, has been compromised; these attacks even seem to affect large, high-profile companies. By entrusting a company with lab book information you can never be 100% guaranteed of its safety. Other problems such as corruption or loss of data can happen if the company does not take backup seriously or in a worst case scenario, become bankrupt and shut up shop. Regardless of these concerns, cloud based synchronisation of the lab book is a major advantage over a traditional hand written lab book.

Document versioning

A major concern about keeping a digital lab book is the possibility of forgery of entries either by adding, removing or editing them after they were originally made. In a traditional lab book entries that are to be removed are ruled out with a single line so they can still be read. Vertical whitespace is kept to a minimum between entries so that it is difficult to add information at a later date without it being obvious. This ensures that all entries in the lab book are kept in sequential order. As far as the authors are aware there is currently no software that enforces the etiquette outlined above; in programs such as Evernote all entries can be edited and removed at the will of the user. Some desktop operating systems and online services do have a feature to save each edit of a document but this is for the purpose of backup allowing the user to revert to a previous version. Currently there are very few pieces of software made entirely for scientific log keeping and the ones available are not stellar.

Collaborative access to data

A huge bonus of storing the lab book data online is the possibility of collaborative access to the data. If more than one person is working on a particular set of measurements then they may need to access records of what data has already been taken, what still needs to be done or of specific measurement setup conditions. This might be done by looking directly in the other person's lab book but with an online system in place the data could be accessed remotely and quickly. This document was produced in such a collaborative manner, both authors set up a Dropbox account and created a shared a folder. A list of tasks was created and delegated to each author and when a particular section was finished it was added to a master document. The document is automatically updated at both ends but problems can arise when both users are editing the file at the same time. A simple service like Dropbox can determine when this happens and then date and stamp the inconsistent version so that both are available. This is not ideal but at least no data is overwritten or lost. There are many specialised revision control software solutions available, mainly aimed at programmers, but generic solutions also exist. Integrating this with digital note taking software on a device such as the iPad may prove challenging.

Persistent storage of a lab book

When the PhD is finished what happens to the lab book? As there is currently no process or protocol for the storage of lab books most of them are taken away by the student once their research is finished. If they are left in the lab they may be kept in a storage cupboard taking up space. A copy of the student's thesis used to be stored in the library however they are but now stored electronically on open access in the University's repository, ORE. A similar system could be proposed for the storage of lab books after the student has submitted their thesis. This might be particularly important if a journal article is scrutinised after publication and if the research student has long since left the University. The online record of the lab book could be used as evidence to defend the research.

6.3 Practical barriers to electronic record keeping

There are certain circumstances when a digital lab book cannot be used or is not the most efficient tool. On the ground floor of Exeter's Physics Building is a clean room, this is used for creating nano-scale electrical devices. All users entering the clean room must wear a protective suit, shoes and gloves. The reason for this is to minimise the spread of dust from clothes and to stop the distribution of the oils found on the skin's surface. Contaminations like these can ruin the quality of devices and therefore the use of a touch screen device would be impractical as it would have to be cleaned every time. Currently, paper lab books are used within the clean room, these are pads of specially treated paper that minimise the creation of dust when written on or moved. These lab books might store information that primarily consists of details of the fabrication method used or instructions on how to use equipment. Information about the fabrication method may only be recalled when writing the journal articles or when creating new devices. This kind of information may be useful for other students who wish to create similar devices but is not easily or readily accessible. If cheap, disposable touch screen covers were available or perhaps by keeping a separate stylus for clean room use only, then these devices could be used inside. A second area where a digital lab book could not be used is in a high magnetic field environment. It is safe for people to enter a high magnetic field providing they are not carrying anything large and metallic. There are two problems that can occur: the electronic lab book itself is likely to be damaged, and; there are health and safety concerns involving the use of superconducting magnets cooled with liquid helium. A pen and paper would be perfectly acceptable in this situation, however in reality notes would rarely need to be made.

7 Costs and funding

Encouraging the use of electronic record keeping could be achieved very cheaply by simply making more people aware of the existence of the tools available. For example, Evernote can be used for free with a monthly upload quota of 60MB per month. A number of members of the Astrophysics Group already use this free version and have no problems with the size constraint. The following is from an email exchange with a member of the Astrophysics Group:

> *I'd be interested to see the stats on how many people use up their full free monthly quota, or have to limit themselves because of it. The way I use evernote so far, I haven't gotten near the limit yet, though that may change.*

If money is to be invested, Evernote offers a premium package to groups at a discounted rate of £2 per person per month for 100+, or £3 per month for 3-99 individuals (http://evernote.com/premium/groups/). A further 50% educational discount may be available if the University qualifies for it. There are similar software packages available however, Evernote appears to be the most established and provides the features that would be needed. Evernote also has optional add-ons such as Penultimate (see Appendix A), which allows for freestyle written entries such as those made with a stylus. However, these extensions do incur additional costs. Inclusion of key add-ons could possibly be negotiated into the group premium package cost.

With regard to funding for any purchasing, PhD students do have a budget for facilities such as computing. However, collating these budgets into something that could be used to pay for a mass premium Evernote subscription would be almost impossible. Problems include the transfer of funds from numerous accounts and constraints from the Research Councils/companies providing the funding who may not wish it to be used for this purpose. The alternative may be funding directly from the University.

8 Privacy, security and protecting research interests

As already discussed in section 2, a lab book serves many purposes, providing both useful records and evidence regarding work that has been done previously. With much focus on open access, it is critical to assess the nature of lab book material and whether or not it is appropriate to share it. Because lab book information is typically not shared with anyone, matters of privacy and security are not usually communicated. It is therefore often unclear, unless the funding body is very explicit (e.g. in projects with defence applications), what restrictions there are on sharing lab book content.

8.1 When and with whom can research logs be shared?

It is important that open access does not compromise the researcher who is making information available (otherwise the only ones to survive will be those who do not share). Lab books contain many key pieces of information such as:

- Ideas for future work, possible extensions to the research.
- Research methods/techniques.
- Results and calculations.
- The path followed in research.

Information such as the above may have a detrimental effect on the researcher if it is released prematurely. For example, it may permit other researchers to publish first by using the lab book details. It may also cause competitors to publish a paper of poorer quality to get there first if the research logs suggest that a publication is near.

In practice, during the PhD lab book information may be shared with colleagues within the same university. However it is more common for the researcher to communicate the information by some other means, such as verbally or by email. Outside of the university lab books will almost never be directly shared.

After the PhD, lab books may be retained by the researcher, taken with them to a new position, or left behind for use by the group. If left behind, lab books would be stored in common areas on bookshelves or with the ex-supervisor of the researcher. Realistically at this stage the lab books would almost never be used unless someone was working on something very specifically of the nature of the research undertaken in the lab books. They hold little use as general reference documents. Any techniques detailed in the lab book are usually already transferred to others who need to use them via peer-to-peer tutelage.

8.2 Privacy, copyright and ownership

In addition to protecting research interests lab books can also include personal data, such as phone number and email address, that will be protected under the Data Protection Act. Personal information should not be shared with unknown recipients (e.g. on the web) without the permission of the person to whom the details apply. Ownership of lab books is typically held by the researcher. However, some research is funded by commercial groups who will have ownership over the content in the lab books. Some areas of research are also of a sensitive nature, for example regarding defence. As such, even once the researcher's interests are protected there are a number of other complications regarding the publication of, and free access to, lab books.

8.3 Freedom of information (FOI)

Freedom of information does not usually feature in Physics, since most research is freely accessible in one form or another. For example, the majority of papers are available on ArXiv (http://uk.arxiv.org/). Furthermore, in the event of an external party wishing to view data, it is likely to happen much more efficiently by contacting the research group directly rather than through an FOI request. The only time that data will likely not be shared is if it is protected by the funding body (e.g. if the project is funded by a defence firm).

8.3 Security

Given the confidential nature of material contained in lab books it is important that any storage that is not intended for widespread distribution be secure. Therefore if this information were to be hosted by the University, for example on the ORE repository, it is likely that security checks would need to be added to ensure that only those who have ownership of the data can access it. The alternative is external storage of research data, for example if records are kept using Evernote.

9 Conclusions and suggested actions

In this section we provide individual assessments regarding suggested actions and then combine the two in a short overall conclusion.

9.1 Assessment from Thomas Haworth

From what I have observed during this case study, I feel that we are currently in a middle–phase where we can see a place for electronic lab books in research but the means to implement it are not yet optimal. People want the added security, backups and ease of searching, etc., which come from electronic record keeping, but the ways in which notes are kept are not yet refined enough. This is particularly the case when it comes to novel working environments (e.g. a clean room or other laboratory rather than an office). I think it would be better to wait a couple of years, allowing for the technology and software to be refined and then to carry out any implementation properly, rather than to rush into it and do it badly.

In the meantime, it is clear that a number of people have already begun to explore electronic lab books using Evernote (see testimonials in Appendix B). They require no funding to do this, making use of free accounts. These people all work at a computer most of the day, not requiring pen and paper calculations or lab equipment, so are in a position to use electronic lab books more readily. There are two important points to take from this:

- People are interested in exploring electronic lab books themselves at zero cost to the University. Simply advertising the fact that electronic lab books exist and are an option will induce more people to use them.
- These people are also the ones who will pave the way, trying new hardware and software as it becomes available and gaining the long term experience which will really reveal whether or not a given tool works.
- As a final note, recurring feedback from colleagues regarding their use of electronic record keeping is that it should not be forced upon anyone. Therefore if any action is taken it should be in a supporting role and not a demanding one.

9.2 Assessment from David Hudson

It is my opinion that the digitisation of existing handwritten lab books would be of little benefit to anyone due to the practical limitations of a) scanning each individual page and b) the lack of ability to search the document afterwards. I believe that digital lab books in the future will become an excellent research tool allowing authors to collate and manage their work in a far better way than the currently accepted standard. Also, due to the increasing focus on the open nature of scientific research, in the future universities may have to be prepared to share the details of the lab book after publication.

The current major drawback of using a digital lab book is the lack of specialised software available. There are many different applications which, when used together, would provide all the functionality desired from a digital lab book but there are currently no applications that have an entirely scientific focus. Evernote is probably the most useful platform currently available and an account can be created for free; this has most benefit to users who work in theoretical disciplines and will do most of their work on a computer. For experimental students a tablet would be more useful as it can be taken wherever the student has to go. As discussed earlier, a tablet which could also function as a desktop machine when docked to a monitor, keyboard and mouse would be the most practical.

My overall conclusion is that the lack of specialised software and the high cost of a tablet are the main barriers to rolling out digital lab books across the University. This may change in the near future but until then Evernote provides a useful free service.

9.3 Agreed overall assessment

The common conclusion is that electronic lab books have a lot of positive things to offer, but are likely to advance significantly in the near future. Furthermore, existing free software is already available and being explored by researchers. As such we conclude that new software and hardware solutions should be monitored, as it is likely that something more appropriate will be available in the near future, but we do not recommend a financial investment at this time.

Appendices

Appendix A: Summary of note keeping software

A.1 Evernote - multi OS - £variable - http://evernote.com/

Evernote is 'note taking' software, where (assuming the appropriate add-ons are purchased) notes can be photographs, text, screenshots, audio recordings, or handwritten notes. The entries are stored in notebooks, meaning that different projects can be segregated. A screenshot from a trial notebook of Tom Haworth is given in Figure 5, showing a list of entries with previews of the content. As well as text, the illustrated entries include photographs of a computer screen and some hand written equations/tables on paper. Evernote incorporates the useful feature that if an entry is modified then the date of editing will be stored in the 'Note info', improving its power as a body of evidence. However, the details of what was edited cannot be viewed unless a premium account is purchased. As discussed in the main document, Evernote can be used for free but requires a premium account for additional storage (free gives you 65MB/month, premium 1GB/month) and other features such as viewing revisions. In order to make use of the full functionality, additional features have to be purchased separately (c.f. Penultimate below).

A.2 Penultimate - iPad - £0.69 - http://evernote.com/penultimate/

Penultimate is a simple handwriting app that exports to Evernote. The user can create different notebooks for different projects and then write and draw on a blank page. The app is quick and easy to use but lacks some useful features. For instance, there is no zoom function and so any written words will be large in size (due to the lack of sensitivity a typical stylus has compared with a pen). Using this app solely for a digital lab book would be far too restricting but it is great for jotting down quick notes.

A.3 Notability - iPad - £1.49 - http://www.gingerlabs.com/cont/notability.php

Notability offers a more complete solution for note taking than Penultimate. Notes can be organised into subjects and categories and each new note can be dated and titled. This allows users to be more meticulous in the organisation of data in their lab books. Pictures and audio recordings can be incorporated into the notes and the text can either be handwritten or typed by keyboard. This offers greater flexibility than Penultimate as information from other sources could be copied and pasted into the note and all the text in the notes is searchable. The most useful feature in Notability is a split zoom feature which allows you to write words in the zoomed-in region while having an overview of the sentence. This makes it easy to create neat handwriting which does not take up large portions of the space available per page. Currently Notability would be our preferred choice for digital lab book software on a tablet.

A.4 irisnote - iPad - £Free - http://irisnote.com/

irisnote presents itself first and foremost as a "science lab notebook that replaces pen and paper with secure, accurate, and reliable data management". As opposed to the two previous apps, irisnote is purpose built for science. irisnote is free for personal use and for students but before using the software you are required to sign up to an irisnote account. Its major features appear to be cloud-based document support and the ability to collaborate and share this information with other people. You can import images and text and even store data files, which is an advantage over Notability. Where it falls down is in the lack of ability to handwrite notes and more importantly the version that we used crashed when trying to access most of the features. In its current form we do not find this software useful but if it is improved in the future then it has a lot of potential.

Appendix B: Testimonials

I'm a recent convert to evernote. Even after a couple months, It's the e-notebook I wish I had started keeping years/decades ago. In my career, I've have never been able to keep a traditional research notebook, as paperwork is just not how astro is done these days, but a quick copy and paste of graphs with a few quick notes is doing wonders. I was sceptical at first, and I still don't really care for the formatting of the notes themselves, but it didn't take long before it became invaluable.

I don't think simple text-editor notebooks would do much good. I can see now with evernote (likely the others too) whole point is the organisational layout, and the ease of having the notes online, i.e. everywhere. I can also see the usefulness would grow with time. I love the power of instantly searching 17 years worth of email history in mac's Mail, doing the same with a well used e-notebook would be very powerful.

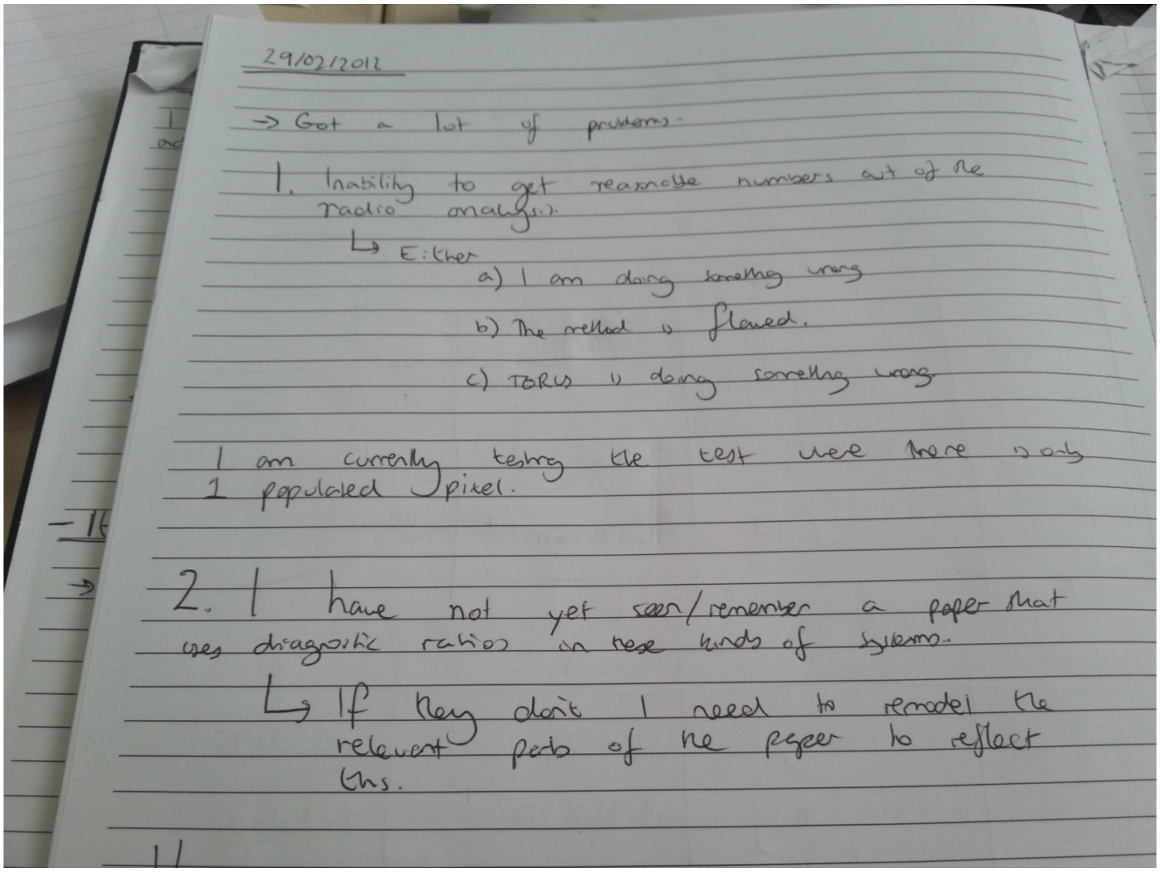
David Sing

Does anyone here make regular use of note-taking software | (i.e. not pen and paper) when they read printed/online papers/books? | Examples would include Evernote, OneNote or any text-editor.

Evernote. Every time...

Alasdair Allan, in response to Nawal Husnoo

Appendix C: Figures



29/02/2012

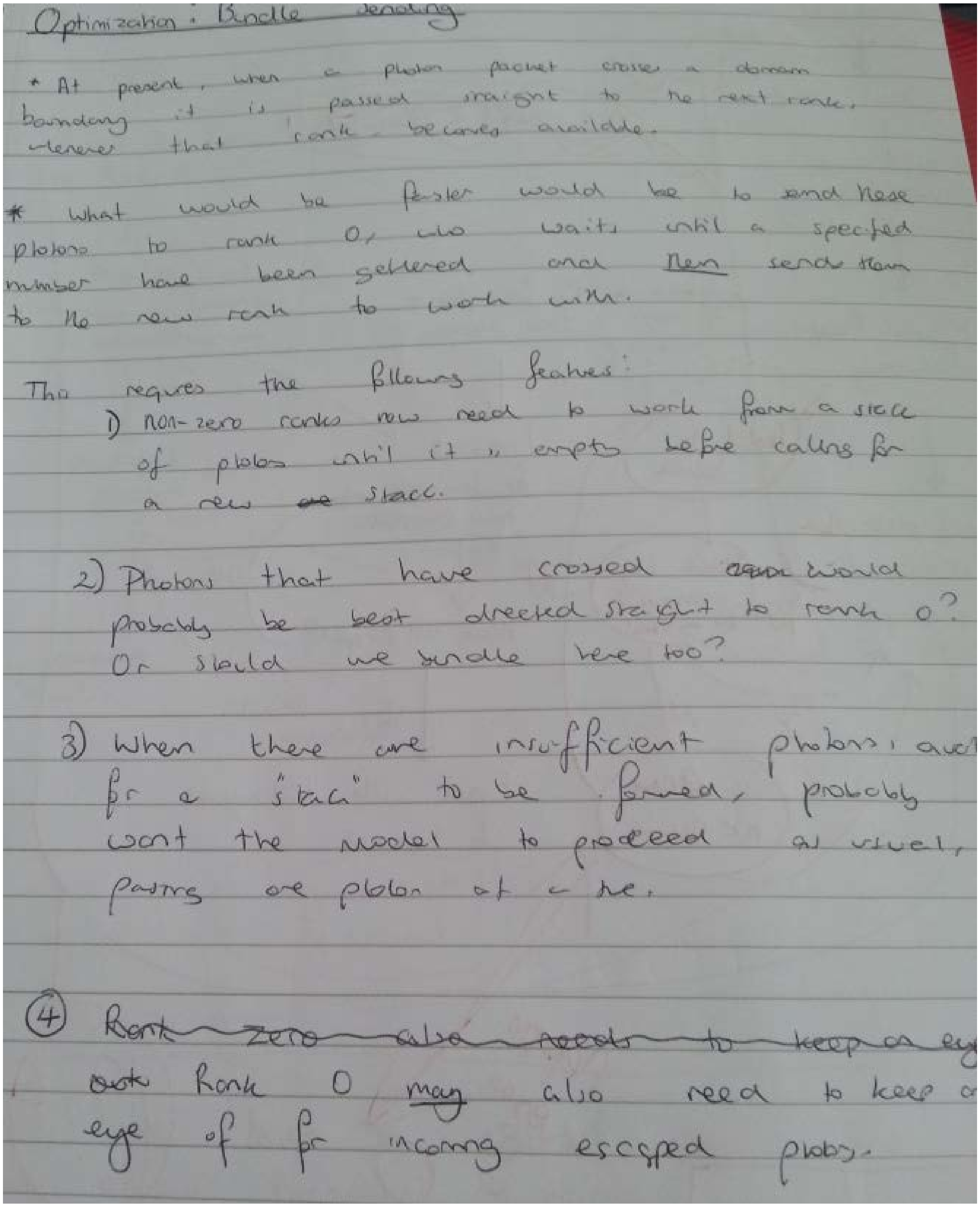
-> Got a lot of problems.

1. Inability to get reasonable numbers out of the radio analysis.
↳ Either
a) I am doing something wrong
b) The method is flawed.
c) TORUS is doing something wrong

I am currently testing the test where there is only 1 populated pixel.

2. I have not yet seen/remember a paper that uses diagnostic ratios in these kinds of systems.
↳ If they don't I need to remodel the relevant parts of the paper to reflect this.

Figure 1: A lab book excerpt from Thomas Haworth. This is an example of a quick summary entry.


Optimization: Bundle sending

* At present, when a photon packet crosses a domain boundary it is passed straight to the next rank, whenever that rank becomes available.

* What would be faster would be to send these photons to rank 0, who waits until a specified number have been gathered and then sends them to the new rank to work with.

This requires the following features:

1) non-zero ranks now need to work from a stack of photons until it is empty before calling for a new ~~one~~ stack.

2) Photons that have crossed ~~again~~ would probably be best directed straight to rank 0? Or should we bundle here too?

3) When there are insufficient photons, and for a "stack" to be formed, probably want the model to proceed as usual, passing one photon at a time.

4) ~~Rank zero also needs to keep an eye~~ out Rank 0 may also need to keep an eye out for incoming escaped photons.

Figure 2: A lab book excerpt from Thomas Haworth. This is an example of an overview of a problem that needs to be tackled, including potential avenues to pursue.

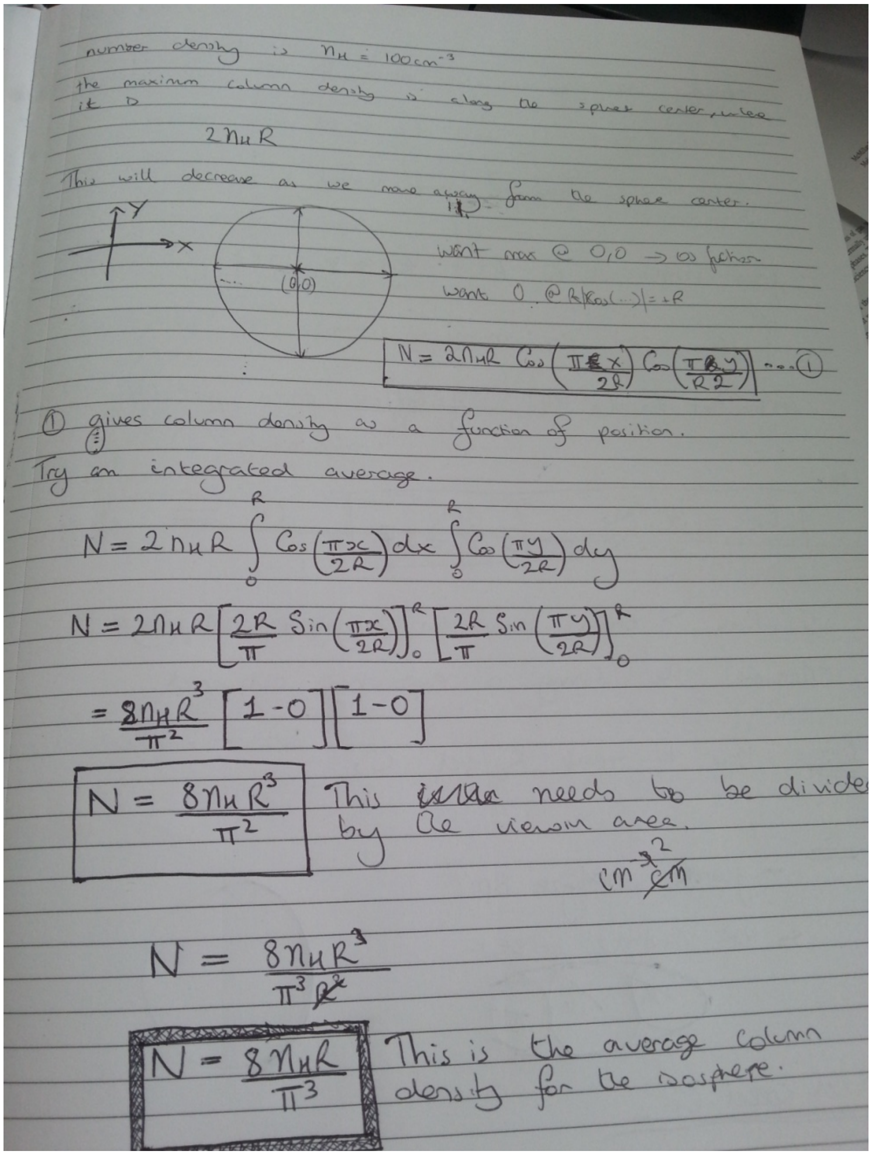


Figure 3: A lab book excerpt from Thomas Haworth. This is an example of an entry that includes mathematics and diagrams. This is the kind of entry that will be difficult to make electronically.

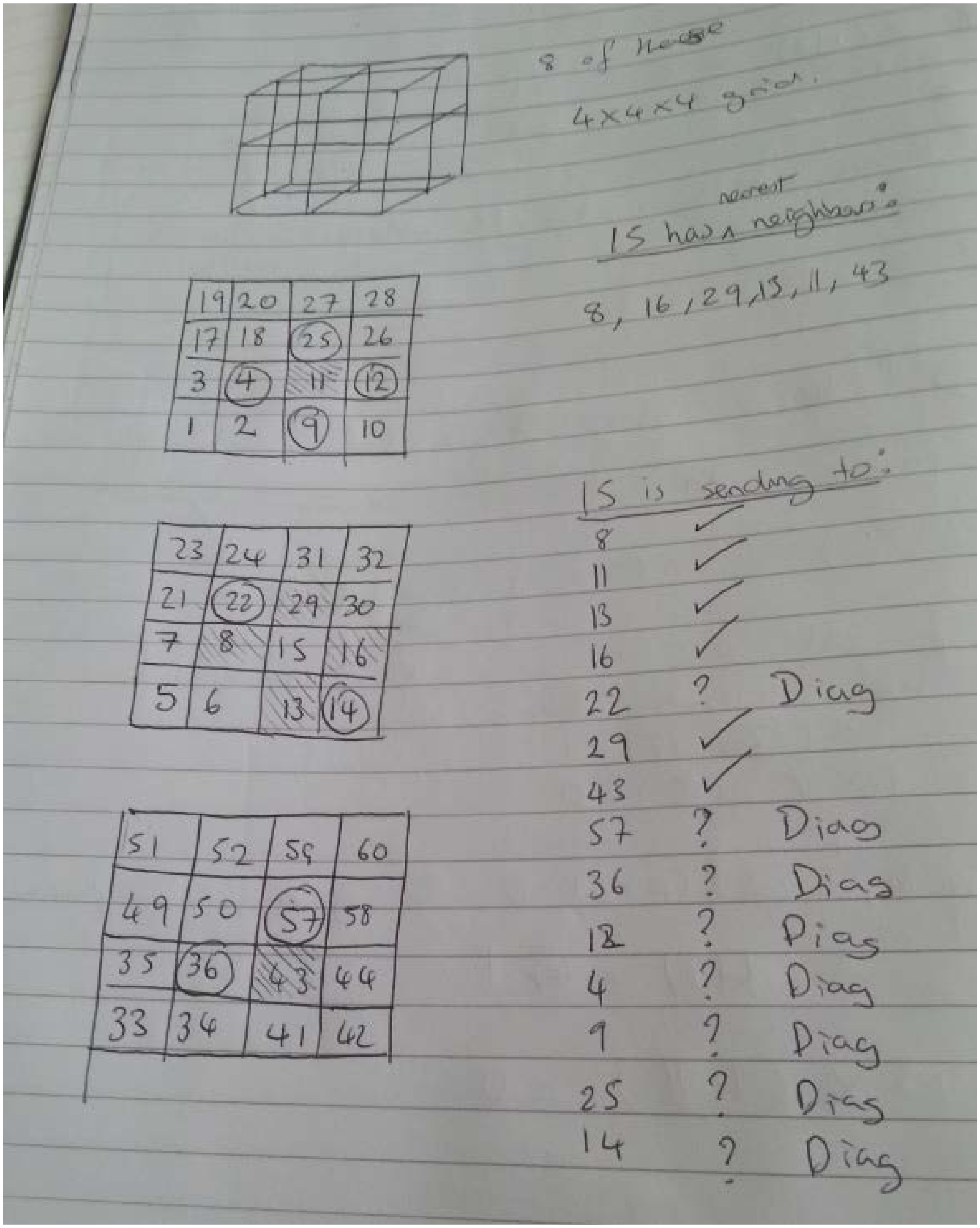


Figure 4: A lab book excerpt from Thomas Haworth. This is an example of some diagrams. Entries such as this will be difficult to produce electronically.

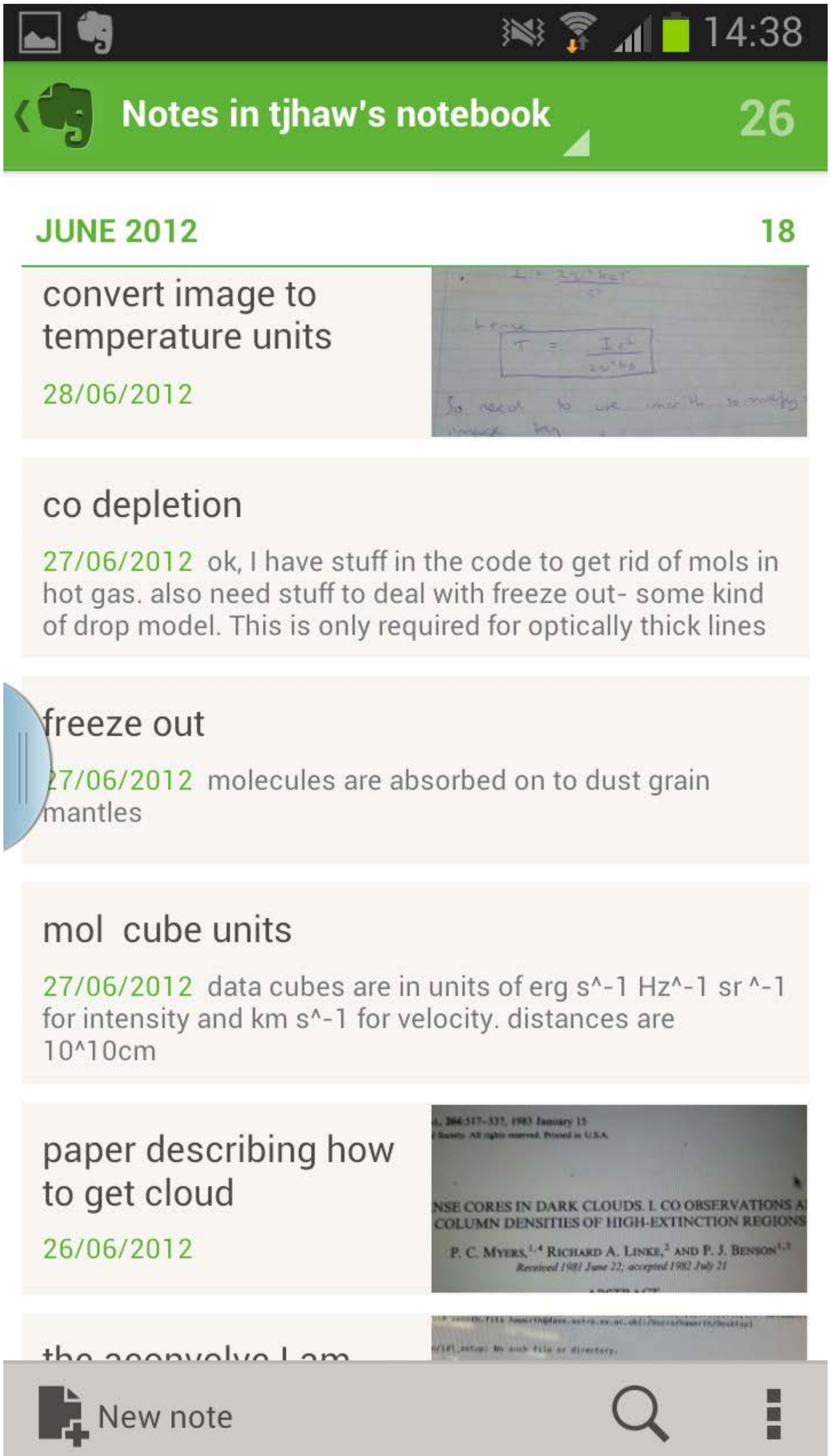


Figure 5: A list of notes from a trial Evernote notebook used by Thomas Haworth. Included are previews of a list of entries, including text and photographic notes.