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Abstract

Paper Laboratory Notebooks (PLNs) have been used for centuries to document and archive the thoughts and work of inventors, scientists, students, and engineers. PLNs are the first formal means of scientific communication we teach our students and, in turn, a student's first training on cultivating and expressing scientific thinking. In the science teaching laboratory, PLNs are at the forefront and serve various purposes for students in the science laboratory curriculum, like good documentation practices and accurate record keeping. This paper discusses the reasons for switching to OneNote ELN, the criteria for selecting OneNote ELN software, how OneNote ELN was introduced and used in the course, and students' opinions on using this ELN. We successfully implemented the OneNote ELN in our General Biology Laboratory II sequence course for biology majors and non-major students entering the health professions. Students had a generally favorable response to using the OneNote ELN; 98% of students agreed that ELNs enabled them to keep a well-maintained laboratory notebook. Overall, student experience with ELNs was positive, with 85% of students indicating that they would recommend other future science laboratory courses they will be taking to adopt the OneNote ELN. In general, the OneNote ELN was viewed more positively in many respects than the PLNs in ease of its usage, access and organizing the notebook.

Introduction

Paper Laboratory Notebooks (PLNs) have been used for centuries to document and archive the thoughts and work of inventors, scientists, students, and engineers (Ghannam et al., 2021; Colabroy and Bell, 2019). PLNs have been used to instill the habit of careful protocol writing, observation, and data interpretation. PLNs are the first formal means of scientific communication we teach our students and, in turn, a student's first training on cultivating scientific thinking and expressing scientific thoughts (Ghannam et al., 2021; Colabroy and Bell, 2019). In the science teaching laboratory, PLNs are at the forefront. PLN serves various purposes for students in the science laboratory curriculum, like good documentation practices and accurate record keeping (Eblen-Zayas, 2015; Higgins et al., 2022; Colabroy and Bell, 2019).

Unfortunately, their several disadvantages of PLNs they are easily damaged can be hard to read if the student has

poor handwriting, or can consume a lot of physical space over time in large research groups (Bloomfield Lee, 2018). The use of PLNs is being slowly replaced since the arrival of digital technologies that led to the switch of electronic laboratory notebooks (ELNs), which have been reported to be widely used in the industry (Eblen-Zayas, 2015; Higgins et al., 2022; Colabroy and Bell, 2019). The integration of ELNs in the science teaching laboratories has been slow (Eblen-Zayas, 2015; Higgins et al., 2022; Bloomfield Lee, 2018; Colabroy and Bell, 2019; Soltau, 2020) because of lack of resources, unstandardized regulations, data security concerns, and lack of motivation for changes (Riley et al., 2017; Guerrero et al., 2019). ELNs have been implemented in science teaching laboratories in some universities (Riley et al., 2017). Researchers have indicated several benefits of ELNs instructors can provide feedback remotely, typed text (handwritten notebooks can be hard to read), flexibility, ease of storage, searchability, and students can easily collaborate with their peers (Higgins et al., 2022). Several types of ELNs have been used in the science teaching laboratory because several vendors have launched free or low-cost versions (Riley et al., 2017; Higgins et al., 2022). These include PerkinElmer's ENotebook, BIOVIA Notebook, LabArchives, Lab-Guru, EverNote, WordPress, Wikis, Blogs, and OneNote (Bloomfield Lee, 2018; Colabroy and Bell, 2019).

OneNote is a free ELN program accessed through tablets, computers, and smartphones. OneNote is designed as a note-taking software with features similar to a PLN that has been digitized. OneNote is organized into notebooks with three levels of organization: section lists, subsections, and pages. OneNote integrates free-hand drawing, typewritten text, and images ((Riley et al., 2017; Colabroy and Bell, 2019). OneNote is compatible with PowerPoint and Excel graphs; tables and files constructed in these programs can be easily exported to OneNote. Smartphones and tablets can be used for audio and video recording, image capturing, and uploading into OneNote (Riley et al., 2017; Grijalva-Borja et al., 2020). OneNote can also allow collaborations with other laboratory partners in a group, one to organize notebooks, attach notes, images, diagrams, and different multimedia elements, including audio, videos, recordings, and captures (Riley et al., 2017; Grijalva-Borja et al., 2020; Colabroy and Bell, 2019). This paper discusses the reasons for switching to OneNote ELN, the criteria for selecting OneNote ELN software, how OneNote ELN was introduced and used in the course, and students' opinions on using this ELN. The ELN we decided to implement is OneNote; it has been reported to be a flexible platform (Grijalva-Borja et al., 2020; Colabroy and Bell, 2019; Bloomfield, 2018).

Moving from Paper-Based Laboratory Notebooks to Electronic Laboratory Notebooks

In the General Biology Laboratory II course sequence at the University of Detroit Mercy, we transitioned from PLNs to OneNote for Windows 10 as an ELN format (initially in one of the sections). Informal initial polling indicated that almost all students had never used ELNs for laboratory courses, but most were open to trying OneNote. Students in the General Biology Laboratory II course at the University of Detroit Mercy have used the OneNote ELN for the past year. Several web-based tools were evaluated a preference for software the students already used or interfaced with word processing programs was necessary for the pilot. In implementing the ELN for the General Biology Laboratory II course, it was essential to include software with low to no cost and with multiplatform abilities. All our students have access to the full version of Microsoft products, which the University offers. This would give them all the capabilities that provide the full functionality of OneNote at no additional

cost. Based on the literature, OneNote seemed to be the best choice for an ELN (Grijalva-Borja et al., 2020; Colabroy and Bell, 2019; Guerrero et al., 2019).

OneNote is a free program that helps collect information, note taking, and collaborations with different users; it allows one to organize notebooks, and attach notes, images, diagrams, and different multimedia elements, including audio, videos, recordings, and captures (Grijalva-Borja et al., 2020; Colabroy and Bell, 2019; Guerrero et al., 2019). OneNote can be used with digital devices like tablets, smartphones, and computers. Another important feature for students is the possibility of including, within the ELN, a lot of information, such as spreadsheets with results, videos with procedures, and links to articles (Grijalva-Borja et al., 2020; Colabroy and Bell, 2019; Guerrero et al., 2019). A template is provided in the OneNote notebook for each experiment unit of the laboratory (all experiments span one laboratory period). Students copy and paste the laboratory report template to their individual OneNote notebook folders. During the laboratory, students add data, observations, analysis, discussion, and conclusions. Faculty provide weekly grading (when possible more often) as they could review the OneNote anywhere with internet access.

In comparison, when the students used PLNs and got feedback fewer times per semester because this included faculty collecting the notebooks that were often hard to read. Sometimes the faculty had to rush when giving feedback because the students needed their PLNs to study for quizzes and exams or to use for the next laboratory activity. Since students wrote their reports electronically, the ELN also saved students time transcribing. Therefore, students had time to review and make corrections prior to the notebook being graded at the end of the week. The ELN allowed for easy data sharing as students worked in groups of four. The OneNote ELN allowed students to work offline, import images, paste hyperlinks, add references, and add applications as needed to enhance the use of the notebook. The General Biology laboratory II was taught by full-time faculty.

OneNote Electronic Laboratory Notebook Template

OneNote Class Notebook is a version of Microsoft's OneNote application specifically designed for use in an educational setting. The application has different areas, including the collaboration area, in which everyone in the class can contribute and collaborate, and the content library, which is read-only for students. Individual student notebooks are areas shared only between an individual student and the faculty, and finally, the teacher-only section that the faculty can only assess. OneNote provides a hierarchical structure that can be adapted to an ELN workflow. Based on this organization, a notebook can encompass unlimited projects (Section Groups in OneNote, experiments can be arranged using at least three hierarchical layers: sections, pages, and subpages. The notebook format begins with three pages that show the slides from the recorded PowerPoint and instructions for the lab activity, and the second page is the laboratory worksheet that the students will fill out and the last section is the quiz (Figure 1). Each student's individual OneNote folder had three sections the laboratory PowerPoint section, the laboratory worksheet section, and the laboratory notes section. Students could add pages or sections to their individual notebook folders. Students added details from their online laboratory manual in the laboratory worksheet section. The laboratory worksheet section changed depending on the data required and included questions. The ELN had a laboratory section template for each weekly laboratory activity (Figure 2). The ELN

template page provided a way to enforce good notebook practices. During the first laboratory section, the faculty gave a short introduction on using OneNote, adding pages and sections, annotating, and uploading images/links/documents.

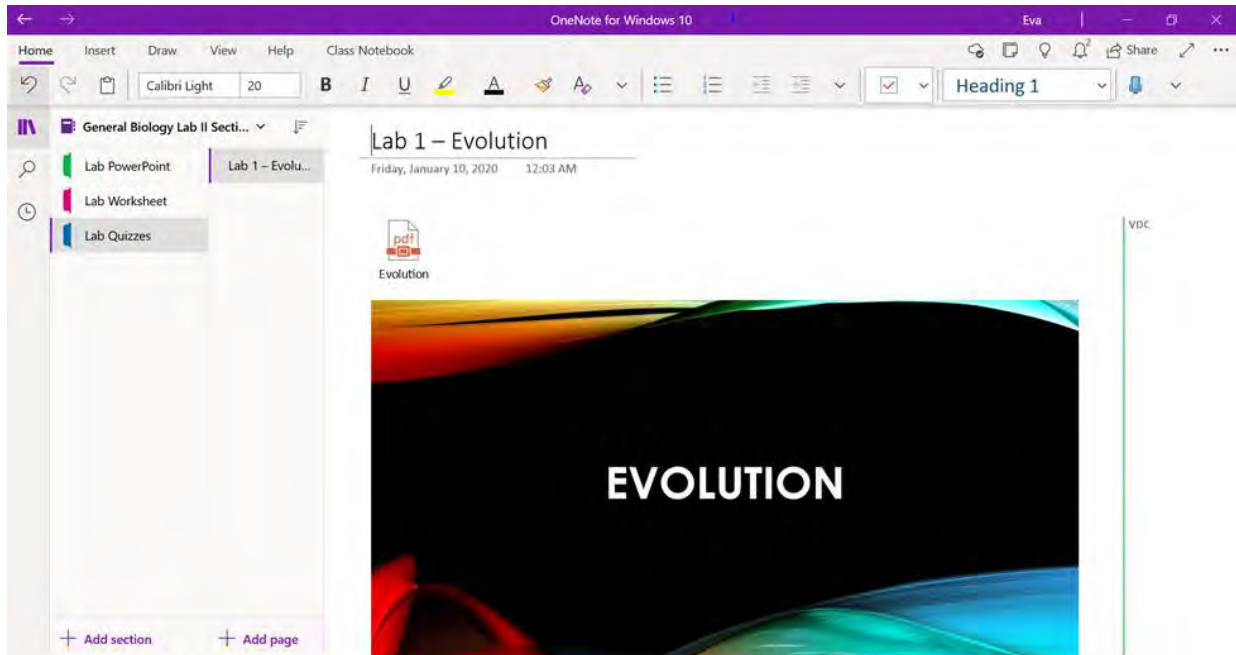


Figure 1. The Welcome Screen of the Laboratory Notebook in Microsoft OneNote

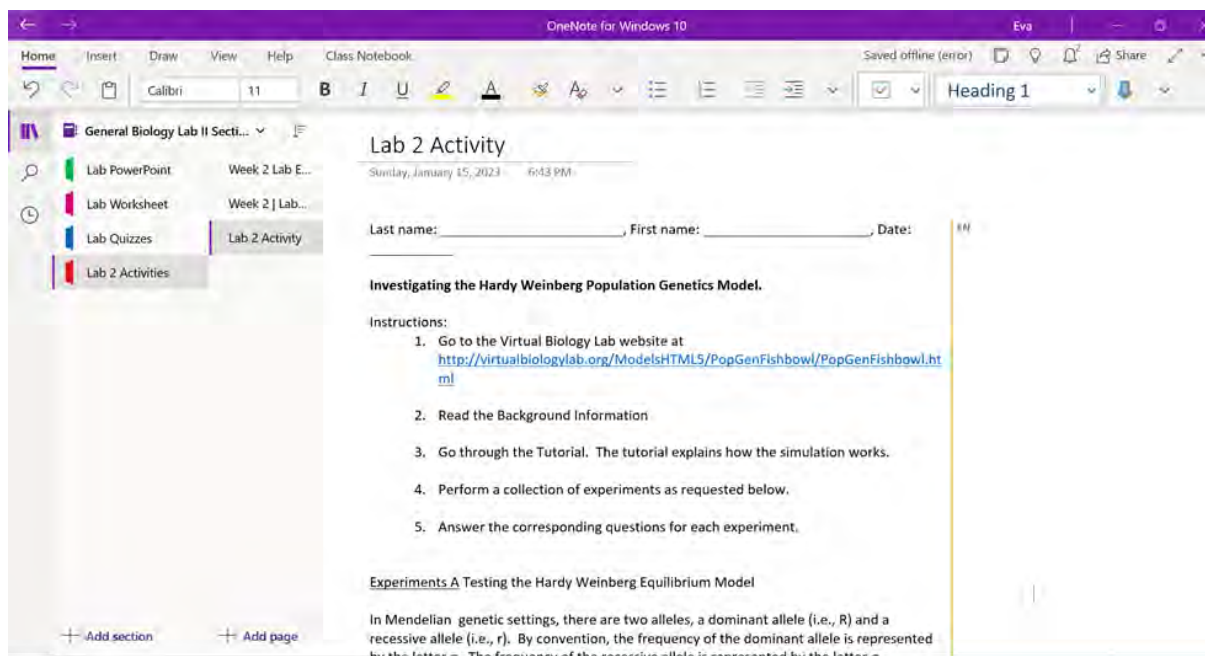


Figure 2. Example of a Page from a Laboratory Notebook, with a Lab Activity

Despite general support for adopting clickers in large courses, gender effects of students' perceptions of BYOD clickers in medium-sized lecture courses are not well known. In order to promote effective and equitable learning, it is important to know whether clickers benefit male and female students equally or to a different degree. The

overarching goal of this study is to describe the influence of gender on students' perceptions of BYOD clickers in an introductory biology lecture. Thus, the guiding research questions were:

R1: What are the differences/similarities between female and male students' perceptions of using clickers in an introductory general biology lecture?

R2: What reasons do female and male students give for their positive or negative use of clickers in an introductory general biology lecture?

Methodology

Students were surveyed in General Biology Laboratory II about the use of the OneNote ELN. Human Subject Research IRB approval was obtained before students were given the surveys (see Appendix). The release of student work and surveys follows the institutional IRB requirements, and all identifying information was removed before analysis. The surveys were administered during the last two weeks of the Winter 2022 semester using a Google Form. The surveys evaluated students' perceptions of using the OneNote ELN. The use of OneNote in the science teaching laboratory is not well understood. Few studies have examined graduate students' perceptions and interactions with OneNote (Oleksik et al., 2014; Guerrero et al., 2016). Moreover, student perceptions of OneNote have been examined in the traditional undergraduate chemistry classroom (Urban, 2017) and Physics (Eblen-Zayas, 2015). However, OneNote has been proposed as an ELN for the traditional undergraduate biology teaching laboratory, and its implementation has rarely been studied (Colabroy and Bell, 2020).

Survey Design

Fourteen questions were designed, which were divided into three categories, to get a better perspective on the results. The first category encompasses the students' general perception regarding the Microsoft OneNote application, which seeks to know the perception of the use of the tool in a general way, with general questions about their experience. Within the second category, the advantages and disadvantages of OneNote were tested compared to the use of a PLN, considering that the use of OneNote has not been commonly used as a laboratory notebook by the students of the study group. Finally, the last category details a general evaluation, by the students, on the use of this tool, in which it is intended to know their final experience, after having already used the tool as an ELN. It also intends to know the students' intention of using OneNote in the future, personally or collectively. Our survey questions were adapted from validated ELN questionnaires by Walsh and Cho 2013, Riley et al., 2017, and Eblen-Zayas, 2015. During the thirteenth week of the General Biology II laboratory course in Winter 2022, students were asked to complete an online google form survey on their perceptions about the OneNote.

Results and Discussion

The laboratory course had enrollments of 36 students during the Winter 2022 semester. Student response counts for the survey were 28 (78% response rate). As this was the students' first exposure to any form of ELN, it was useful to know their experiences to select a permanent ELN. Most of the students 98% reported that they kept a better record of their laboratory work with an ELN than with a traditional PLN, and few students 2% felt their

record keeping was somewhat worse with the ELN (Figure 3). Additionally, most students 91% reported that it took less time to enter information into an ELN as compared to a PLN (Figure 4). When asked if took less effort to organize information in and ELN as compared to the PLN most students 94% agreed and only 2% felt it was somewhat worse (Figure 5). Simple ELNs such as OneNote have a minimal learning curve and allow rapid adoption in in science teaching laboratories by anybody with basic computer skills. OneNote entries begin as a blank document, allowing the user a great deal of freedom in the format and content of entries. Numerous file types can be attached to an entry simply by dragging and dropping and appear either directly in the notebook content or with an icon that can be clicked to open (for larger word documents, spreadsheets, etc).

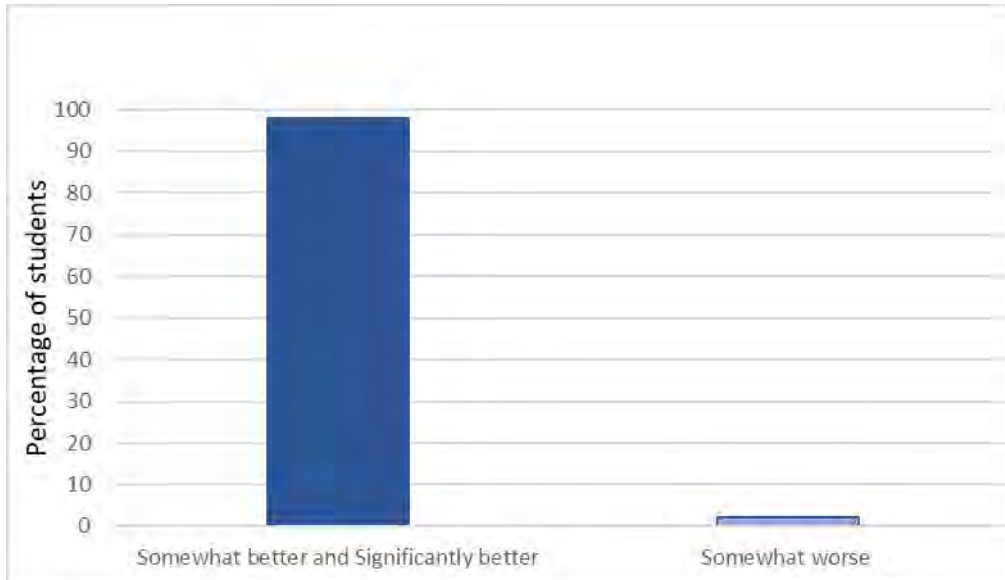


Figure 3. Student Responses to the Question, “Do you keep a better or worse record of your laboratory experiment data with OneNote as compared to a traditional lab notebook?”

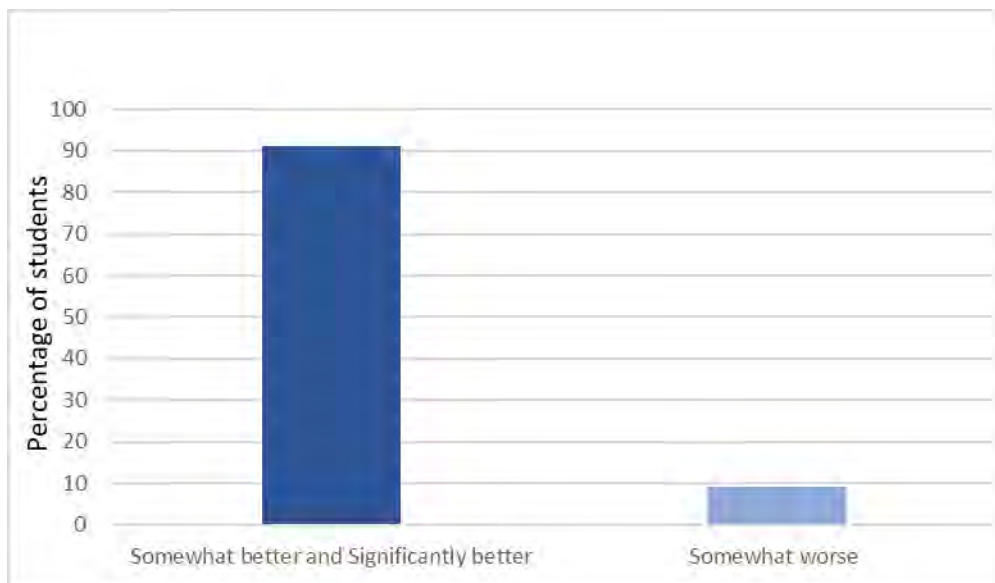


Figure 4. Student Responses to the Question, “Do you feel you spent more or less time entering information into your OneNote notebook as compared to a traditional lab notebook?”

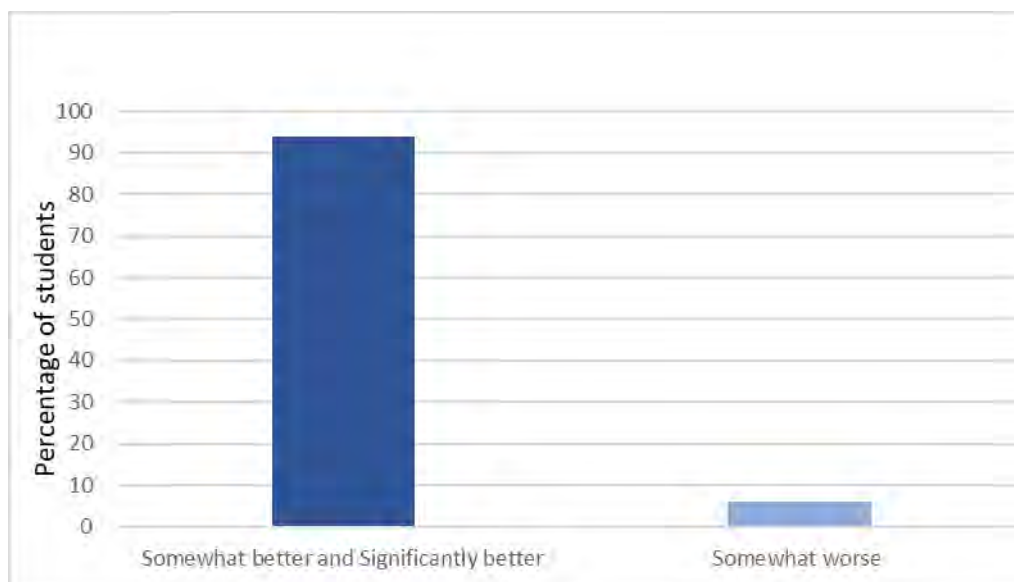


Figure 5. Student Responses to the Question, “The effort required to organize the information in OneNote Lab as compared to a traditional lab?”

Students frequently mentioned that they appreciated the ease with which the information and files could be all found in one place. The list of benefits included “it is easier to find the OneNote materials and the worksheets and what section to study.” “OneNote Lab is easier to organize the materials and lectures clearly. “It is easy to access the professor’s PowerPoints and helps keep in class work organized. “It was easier to keep all my information in one place.” Researchers have reported that some benefits of OneNote are the ease of reorganizing the information, and having all the pages in one page/section which makes it easier for users to access their files and information (Grijalva-Borja et al., 2020; Collabroy and Bell, 2019; Eblen-Zayas, 2015). This shows that the ease of use is an important factor determining how well students adopt ELNs.

OneNote did have some technical issues, particularly with uploading of images which took a very long time, and this was a source of student frustration. Sixteen students (out of 28) somewhat or strongly agreed that technical issues were an impediment to getting work done in the ELN. The list of ELN technical issues mentioned by at least two or more students included “Sometimes things would not load affecting my work.” “Sometimes, it is hard to add my pictures easily. If I add lots of pictures at once, the process goes slow or stop.” “Sometimes One Note takes a long time to load. Overall, just not a huge fan of the format.” This might have been due to connectivity issues of all 36 students uploading images and working on the OneNote activities at the same time. Previous studies have shown that freshman students have some anxiety and fear of various technology tools when the faculty transcend students on the use of technological tools student’s preference varies significantly. Moreover, students report frustrations over loss of an internet connection, software glitches, and crashes, in addition to learning how to use new software features (Collabroy and Bell, 2019; Grijalva-Borja et al., 2020; Collabroy and Bell, 2019) due to students being anxious and fearful of the use technology in the classroom.

When asked to identify what aspects of record keeping were challenging with an ELN was taking notes (2 students) “the only aspect that was more difficult for me with the One Note Lab as compared to a traditional

notebook is the taking notes. I don't like to type my notes and I was allowed to write my notes out which I was thankful for.” “Since the book we use I have is online it is difficult to read the manual and make the notes at the same time.” Technological issues (8 students) “sometimes One Note takes a long time to load.” “Sometimes technological glitches.” Uploading images and editing notes (13 students) “Sometimes, it is hard to add my pictures easily.” “Copy and pasting pictures”. Challenging for students who had never used OneNote before (3 students) “was hard to navigate and learn to use at first.” “If you don't know how to use one note it can be difficult.” Some of the negative feelings toward this ELN could reflect students who do not care to use technology in the classroom or comfort level learning new technology. Several studies have reported that not all freshman are usually comfortable with embracing new technology in the science classroom (Collabroy and Bell, 2019; Grijalva-Borja et al., 2020; Bloomfield, 2018). The inability to freehand draw in OneNote has been cited as the number one disadvantage of using this ELN. Despite the use of stylus and tablet interface, students have reported that tasks involving writing – such as diagrams, equations and sketching – were not improved using OneNote when compared to PLNs. Indeed, as this author has observed, students are much more likely to photograph a paper containing handwritten notes and upload that to the notebook rather than attempting the embedded, digital sketch tools Walsh and Cho, 2013; Van Dyke and Smith-Carpenter, 2017; Collabroy and Bell, 2019; Riley et al., 2017) When the students were asked if they would recommend other laboratory courses to implement OneNote (Table 1). Student response to ELNs generally, and to OneNote in particular, was overwhelmingly positive. 79% of the students would recommend the use of OneNote in another science laboratory course. When asked if they were given a choice of how to keep records in a research or curricular laboratory, 22 out of 28 students said they would choose to use an ELN, and 6 additional students said that their choice would depend on the situation. Of those students who said that their choice would depend on the situation, the biggest factor impacting their decision would be the nature of the laboratory experiment they were working on if it required a lot of data entry. “It depends on how extensive the lab was.” If I have to do a lot of math and/or keep track of certain things, it is a lot easier to write it down quickly rather than trying to figure out how to set up a table or other thing on a laptop.” “If there are diagrams to label and many pictures, I believe that OneNote would be best, but when it comes to just data keeping in an experiment and answering questions, I prefer a traditional notebook/paper copies.” “The type of experiment being done and the workspace available.” Students have reported that tasks involving writing – such as equations– were not improved when using OneNote as compared to PLNs (Collabroy and Bell, 2019; Walsh and Cho, 2013; Van Dyke and Smith-Carpenter, 2017).

Table 1. Percentage of the Results obtained in Question 7

Question	Answer	Percentage
Would you recommend that other laboratory classes adopt the One Note Lab	Yes	86%
	No	14%

An additional factor that may impact student satisfaction with using an ELN is the type of device used to access the notebook. For this course, students could use desktop computers in the laboratories or personal laptops, tablets, or phones to access the software. Students did use a variety of other device combinations to log into OneNote. The survey asked students to estimate the percentage of time during the course that they used a particular device to access OneNote. The estimates varied widely, with some students indicating they used the desktop computers

in the university for 25% of their OneNote access. Other students used personal laptops as much as 100% of the time. One student used a smart phone for 75% of their OneNote access. When asked to identify what aspects of record keeping were easier with an ELN, the three most common responses were easier access (13 students) easier organization (13 students) and lastly for easier review of exams and quizzes (2 students). Some of the listed responses are “I liked using the online lab notebook because it was easier for me to access at anytime and anywhere. This is easier than having to worry about a physical notebook and having to take it anywhere with me when I needed to work on homework. With the online lab notebook, I just needed my computer and I was all set.” “First, I don't need to worry about forgetting to bring the lab notebook if I use the OneNote Lab.” “OneNote Lab is easier to organize the materials and lectures clearly.” “everything is more organized under tabs in OneNote.” “Referring back to previous labs when it comes to studying for a quiz or test.” “With online notebooks, I like the command feature where I can easily find a section I want to review.” Although not physically portable, ELNs are highly accessible with the widespread use of today’s technology. Users can access these web-based notebooks from any online device including laptops, smartphones, and iPads or other tablets, many of which would be carried by the user. OneNote is compatible with both Macs and PCs, has both online and desktop programs, and has applications for iPhone, BlackBerry, Android, and other types of smartphones (Guerrero et al., 2019). The OneNote desktop program may also be used from a personal computer when Internet access is not available and syncs content again when connected. Another distinct advantage to using a web-based system is that all information is kept in cloud storage, erasing the need for shelf space and securing information safety in the event of a computer failure or crash. Several studies have reported another important feature of ELNs is that the students can be able to access their work from any computer or mobile device (Guerrero et al., 2019; Riley et al., 2017; Deborah Bloomfield Lee, 2018)

Conclusion

We successfully implemented the OneNote ELN in our General Biology Laboratory II sequence course for biology majors and non-majors’ students going into the health professions. The sample size was only 28 participants. The instruction dealt with a single content area (biology). Findings from this study might not be representative of other institutions and student populations. This study should be replicated with more students at multiple institutions for maximization of generalizability. Despite these limitations there was generally a favorable response from students in using the OneNote ELN, 98% of students agreed that ELNs enabled them to keep a well-maintained laboratory notebook. Overall, student experience with ELNs was positive, with 85% of students indicating that they would recommend other future science laboratory courses they will be taking to adopt the OneNote ELN. Moreover, ease of use, ease of organizing their materials and ease of access on different devices of their laboratory activities had major impacts on students deciding to switch to using ELNs. In general, the OneNote ELN was viewed more positively in many respects than the PLNs in terms of preparing reports and organizing the notebook. Overall, negative opinions or feelings toward the ELN appear to be in the range of what is reported as students’ reluctance of technology in the classroom. The OneNote ELN was novel to most students and the learning basic steps on how to use and go about it was about two weeks. This may be alleviated by an earlier introduction like posting videos the week before laboratory begins for students to watch. The use of OneNote ELN described in this paper worked seamlessly for the General Biology Laboratory II sequence course

and can be adapted to other life science laboratory courses. In the future, we plan to administer surveys and interview the students in order to examine how the OneNote usage in General Biology Laboratory I and II may impact student performance in these courses and might inform science educators about the pedagogical value of ELNs. All these positive attributes suggest that OneNote ELN could be a common mechanism for laboratory teaching across biology and other disciplines in the future.

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Appendix. OneNote Survey

In order to assess students' perspectives on their use of One Note in the biology lab we request that you complete the following survey.

The following questionnaire contains questions about your opinions on using One Note in lab. For each item, please choose an option that best describes your level of agreement or disagreement about the use of One Note. Indicate your opinion by clicking on only one bubble per item.

Gender

Male

Female

Non-binary

Academic Major (or intended major):

1. Did you find you kept a better or worse record of your laboratory experiment and data with OneNote Lab as compared to a traditional lab notebook

Significantly better

Somewhat better

Somewhat worse

Significantly worse

2. Do you feel you spent more or less time entering information into your electronic lab notebooks compared to a traditional lab notebook?

Significantly better

Somewhat better

Somewhat worse

Significantly worse

3. The effort required to organize the information in OneNote Lab as compared to a traditional lab notebook was?

Significantly better

Somewhat better

Somewhat worse

Significantly worse

4. Technical issues with OneNote Lab were a significant impediment to getting your work done?

Significantly better

Somewhat better

Somewhat worse

Significantly worse

5. The training you received was sufficient to use OneNote Lab effectively?

Significantly better

Somewhat better

Somewhat worse

Significantly worse

6. Using the electronic lab notebook in this class improved my technological skills?

Significantly better

Somewhat better

Somewhat worse

Significantly worse

7. Would you recommend that other laboratory classes adopt the OneNote Lab?

Yes

No

8. In the future, if you were given the option to choose how to keep a record of your work, would you choose:

- To use a traditional lab notebook
- To use an electronic lab notebook
- It depends

9. If you answered it depends), in question 8 what would impact your decision?

10. What percentage of the time did you use these devices to access OneNote Lab

- a) UDM computer _____%
- b) Other desktop computer _____%
- c) Personal laptop _____%
- d) Cell phone _____%
- e) Personal tablet _____%

11. What aspects of the record keeping are easier with OneNote Lab as compared to a traditional lab notebook?

12. What aspects of record keeping are more difficult with One Note Lab as compared to a traditional lab notebook?