Electronic notebooks in a classroom setting: Results from a senior-level forensic chemistry course

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Abstract: The use of electronic notebooks in forensic science education offers benefits of improved accessibility and enhanced group collaboration. However, their use in the forensic science classroom remains unexplored. This study investigates the use of electronic notebooks in a senior-level forensic chemistry course, exploring two research questions: 1) How do students value electronic notebooks as they contribute to their learning in a classroom setting, and 2) What are the potential barriers to the use of electronic notebooks in a classroom setting? Data collected over two semesters of the course using a modified version of the Student Assessment of Learning Gains survey suggests that students found the notebook helpful for their learning and valued the in-class activities facilitated via the notebook. The findings suggest that electronic notebooks can enhance lecture-based courses by promoting engagement and collaboration, though guided implementation is needed to mitigate initial barriers.

Keywords: electronic notebooks, **forensic science education**, **student-centered learning**, **collaborative learning tools**, **instructional technology**

Introduction

Electronic notebooks have begun replacing traditional paper notebooks in undergraduate laboratory courses across scientific disciplines (1). Electronic notebooks reportedly provide benefits over paper notebooks including making data more accessible and collaboration more efficient (2). However, barriers have also been reported such as learning curves for users (3). As electronic notebooks gain prominence in lecture-based courses such as forensic chemistry, it is crucial to understand how they enhance student learning while identifying potential challenges.

Electronic notebooks in lab courses have commonly been used to provide a structural framework for students to organize their data (4). The electronic notebooks were tailored to the specific lab and organized into four sections (pre-lab work, an in-lab discussion, in-lab work, and a post-lab assignment). The students were responsible for filling in those sections as they progressed through the lab. In an engineering lab, the electronic notebook served not only as a structural framework but also as a platform for students to collaborate (3). Students were grouped into teams with one student assigned as the "notebook leader". Teams recorded their data and worked together on the shared platform where all the material was easily accessible; they would later submit the electronic notebook for grading. This approach is common in other implementations described in the literature (3,5,6).

Electronic notebooks have been credited with facilitating interactions among peers, and between students and instructors. Hall and Vardar-Ulu (4) emphasized that students improved in proposing hypotheses, exchanging ideas, communicating thought processes, and applying critical thinking skills during the pre-lab work section of the lab after using the electronic notebook. Riley and colleagues (3) noted similar facilitation as the electronic notebook served as a platform for data sharing, which led the students to collaborate as they worked together in one notebook for data submission. Electronic notebooks also facilitate more efficient feedback, grading, and monitoring of students' work. Instructors leave feedback as comments in the electronic notebook which is readily available for students to read (5,6). Instructors are also able to resolve student questions such as grade appeals within the electronic notebook (5). Both instructors and students report seeing value in the electronic notebook as it facilitates interactions (5,6).

Electronic notebooks also offer flexibility and adaptability features. The electronic notebook allows students to make revisions more efficiently. Using timestamps allows for "repeated revisions" with time-tracking (3). Instructors benefit from the ability to monitor and grade students' work through the features provided by the electronic notebook. For example, the electronic notebook allowed for an easier time evaluating student work compared to traditional paper in terms of grammar, punctuality, and writing by eliminating the

difficulty in discerning illegible handwriting. Overall, instructors noted a "pleasurable" experience given the electronic notebook's accessibility and adaptability (5,6). Another accessibility feature that added value for both instructors and students was that collaboration and communication could be facilitated remotely and/or asynchronously (6). Instructors could check student notebooks outside of class and students could work together without having to be physically in class. Overall, the electronic notebook appears to be favored over paper notebook in terms of accessibility/adaptability for instructors and students alike.

A notable disadvantage of the electronic notebook was the learning curve to fully understand the intricacies of the electronic notebook. This was primarily because instructors did not provide a standardized template for the students while they were learning how to use the electronic notebook. Providing a standard template for first-time users is a simple remedy that can aid students in their understanding of using the electronic notebook (6).

The Present Study

While the use of electronic notebooks in a laboratory setting has been reported, research is lacking that describes their use in the classroom. We hypothesized that, given the reported advantages of electronic notebooks—such as making data more accessible, enhancing collaboration, and simplifying the tracking of changes—similar benefits may be observed in classroom settings as courses shift toward student-centered teaching formats. While some of these advantages may be available in the LMS (learning management system, e.g., Canvas), the electronic notebook offers more flexibility of use and seamless collaboration. Unlike the LMS, electronic notebooks allow for real-time collaboration and the ability to contribute handwritten content using a stylus and tablet. Given the nature of the course (i.e., the need to draw chemical structures, solve mathematical problems, etc.), a collaborative tool that allows for handwritten content was necessary. Given the direct connection between lab and lecture courses in forensics, the purpose of this study is to investigate forensic science students' experiences using electronic notebooks in a lecture course to assess if the electronic notebook could present similar advantages to students and instructors as seen in the lab setting. The following research questions (RQ) were explored:

RQ1: How do students value electronic notebooks as they contribute to their learning in a classroom setting?

RQ2: What are the potential barriers to the use of electronic notebooks in a classroom setting?

Methods

The research presented in this paper adhered to the ethical guidelines outlined by the University of Central Florida Institutional Review Board.

Study Setting and Participants

Students in an upper-level forensic chemistry course at a large, doctoral-granting institution were surveyed for this study. The course was taught using the Team-Based Learning (TBL) framework which is a highly structured form of small-group learning that emphasizes student preparation outside of class and the application of knowledge in small learning teams in class (7). A detailed description of the TBL model and flipped classroom used in the course can be found in previous publications (8,9). For the context of this paper, it is important to note that the TBL approach includes implementing a flipped classroom. No class time was used for lecturing or delivering course content. Class time was used for group work (application activities) and the TBL readiness assessment process. The in-class application activities were assigned and completed in the Collaboration Space of a OneNote Electronic Class Notebook (i.e., the electronic notebook referenced in this study). OneNote was chosen in this case because the application is linked to students' institutional accounts, but other collaborative platforms (e.g. Google Drive) may be used as well. Each team was assigned a section in the Collaboration Space in

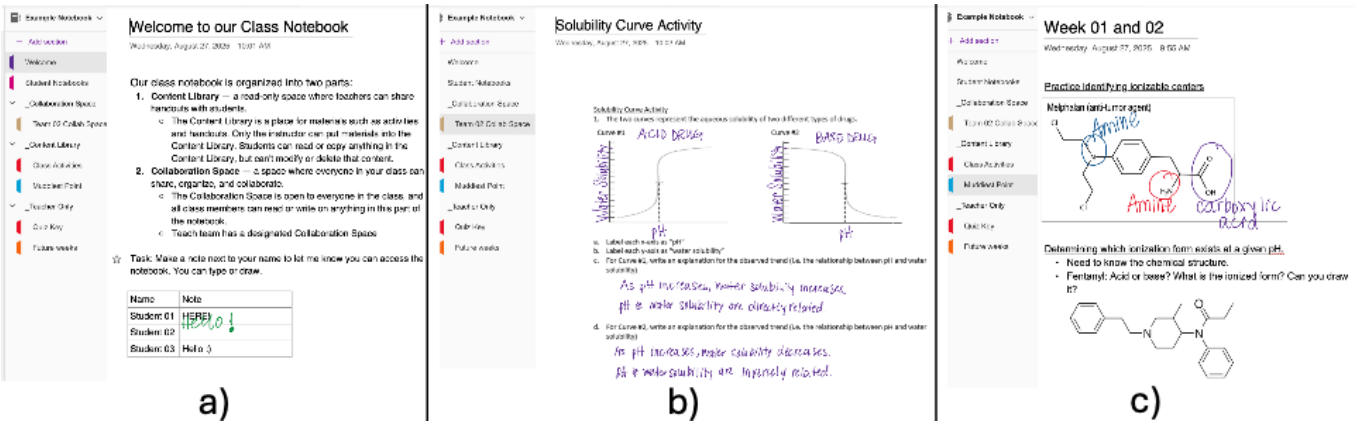

FIGURE 1 Screen captures of digital notebook a) welcome page, b) team space, and c) content page

the electronic notebook.

Prior to the start of each class meeting, the instructor posted the application activities to the electronic notebook for each team (same activity for all teams). Teams worked together during class time to collaboratively answer the activity questions within the electronic notebook. The instructor could see student progress in real time, was able to provide feedback to each of the teams as well to use the electronic notebook to show the class different approaches to answering questions. The electronic notebook also served as a record of the activities – students had access throughout the semester even while the instructor was grading. The use of the notebook provided student support by providing a resource for reviewing class activities, aiding in test the final exam preparation, and ensuring that students who were absent could stay engaged by accessing their team's electronic entries. **FIGURE 1** provides screen captures of the digital notebooks showing a) the welcome message and explanation of the notebook organization, b) an example of the collaborative team space, and c) an example content page showing a muddiest point class discussion.

Data Collection and Analysis

In the fall 2021 and fall 2022 semesters, 21 students responded to a modified version of the Student Assessment of their Learning Gains (SALG) survey (10). The SALG is a free online survey tool that can be used to measure how well a course supports student learning. It captures student perceptions of their progress and the effectiveness of course components, helping instructors identify strengths, address weaknesses, and improve their teaching. To address the research questions, four Likert-scale questions from the SALG were used. The specific questions were:

HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING?

1. Electronic class notebook
2. Attending class meetings
3. Going over problems in my group
4. Working with peers during class

The last three items were considered relevant because the notebook was used in class to facilitate group work. Students responded on a Likert scale to assess the gains made from using the electronic notebook on a scale from 1 (none) to 5 (great). One open-ended question was added related to the use of the electronic notebook: *Please comment on how the use of the electronic notebook supported your learning in this class.*

A thematic analysis (11) of the students' responses to the open-ended question was used to identify themes related to students' perception of learning related to the use of the electronic notebook and activities related to the use of the electronic notebook. For our study "perception of learning" refers to how students think about their own learning and how it is affected by the use of the electronic notebook and associated activities. The first author used open coding to analyze responses to the open-ended question (12). Codes were combined into broader themes. These themes, and the application of codes, were reviewed by the second author for validation. Both authors discussed any disagreements in the application of codes and identifications of themes and came to a consensus.

Results

RQ1: How do students value electronic notebooks as they contribute to their learning in a classroom setting?

To answer RQ1, we analyzed responses from four questions of the SALG survey that directly probed students' perceived value of the electronic notebook or probed aspects of the course that were affected using the electronic notebook. Student responses to these questions are presented in **FIGURE 2**. The first survey question probed students' perceived value of the electronic notebook itself. The survey results show that 76% reported that the notebook provided a little help (35%), or much or great help (41%). We further investigated other aspects of the course that the electronic notebook facilitated directly or indirectly in an attempt to explain this result.

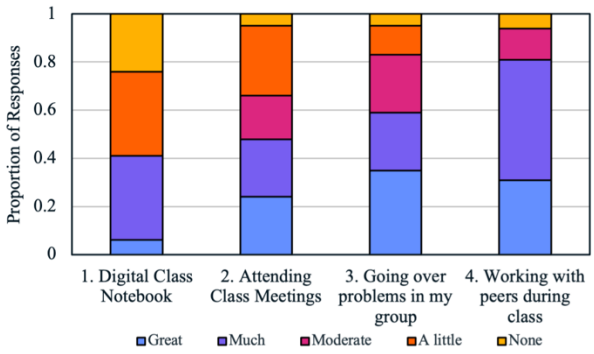

FIGURE 2 Student responses (N=21) to select questions on the SALG. *How much did each of the following aspects of the class help your learning*?

As the electronic notebook was predominantly used during class time, we hypothesized that the question probing students' perception of the value of attending class could, in conjunction with other questions, be used to interpret perceptions about the value of the notebook. Question 2 of the survey asked students about the relationship between attending class and their learning. In

total, 95% of the students reported that attending class meetings was helpful (sum of *a little – great*).

Students were also asked how going over problems with their group (survey question 3) and working with their peers during class (survey question 4) helped their learning. Most students reported significant value in these two aspects. 59% of students indicated that going over problems in groups was great or much help in their learning; 36% indicated it was moderate or a little help. 81% of students indicated that working with peers during class time was great or much in their learning; 13% indicated it was moderate help.

Given that the electronic notebook was used to facilitate group work during class time, the responses to these three questions could be attributed to the notebook's affordance for students to share a common platform that allowed efficient communication and collaboration. This aligns with multiple accounts in the literature that the electronic notebook facilitates learning engagement by serving as a platform for collaboration (3). These results were triangulated with a thematic analysis of students' responses to an open-ended question about the notebook (*Please comment on how the use of the electronic notebook supported your learning in this class.)*. This question provided additional insight to how the electronic notebook may have facilitated aspects of the course that students reported finding valuable to their learning. Two themes related to the value of the electronic notebook were revealed in their responses: learning engagement and social interactions.

The first theme was learning engagement which described how students perceived the electronic notebook tool for facilitating their interaction with course materials. Based on the responses, students primarily defined their learning engagement by the ability to organize course materials efficiently. One of the students explained:

> *It was a very fast and easy way to find and share all of the work done in class. I much preferred being able to just go into the app and find any paper I wanted as opposed to rifling through stacks of handouts. Very convenient once the initial learning curve is surmounted.*

The organization provided by the electronic notebook allowed students to access and review classwork more easily than they could with hard copies of assignments. Prior literature also explains how students appreciated certain components that the electronic notebook facilitated which directly applied to the organization. For example, the analysis done by Riley (3) showed that the electronic notebook allowed the students to easily archive their data and be able to revise the material efficiently by using the timestamps feature. The ability to easily archive the data translates to being able to organize material proficiently and being able to access it with relative ease.

The second theme was social interactions which described how students used the electronic notebook to interact with their peers. Students also perceived high value in working with their peers according to the survey results. Their comments on the open-ended response help to interpret that perception in the context of the electronic notebook. One student, referring to reviewing their peers' work in the notebook said:

> *It was helpful to see other's work and remember back to cover it in class. Having multiple people asking questions and giving answers helps me to remember the main points as it is more like a conversation than a lecture.*

Students also recognized the value of the notebook in facilitating interactions during a time when face-to-face interactions were limited:

> *Especially during the times of the pandemic, it was helpful for my classmates to upload their answers to one note and as a class go over all their responses. In the past courses, it was difficult for students to share their responses to the class but this approach made it easier to access our responses.*

Our results in the lecture course align with the literature on lab courses that describe the value of the electronic notebook in facilitating social interactions. Specifically, the analysis done by Hall and Vardar-Ulu (4) showed that there was an improvement in overall communication which the responses left by the students indicate as well. It can be reasonably concluded that students valued explaining their work to others and working with peers during class and that the electronic notebook helped facilitate these activities, especially during the pandemic when social interactions were more challenging to navigate.

Analyzing the students' responses in total showed that the influence of the electronic notebook on both learning engagement and social interactions was perceived favorably by students.

RQ2: What are the potential barriers to the use of electronic notebooks in lecture courses in a classroom setting?

The second research question addressed barriers to using electronic notebooks and how they could potentially negatively impact the student experience. This research question was addressed solely using themes that emerged in the open-ended response question on the survey.

The most notable barrier to the usage of the electronic notebook is the learning curve associated with using a new instructional technology. Speaking on behalf of their peers, one student said:

> *I personally already use OneNote and the related Microsoft programs for my learning[…] Peers who have not used OneNote and the related programs often find it confusing and complicated.*

As with any instructional technology, effective implementation relies on students dedicating time to learning how to use the electronic notebook. This could explain why students perceived less value in the electronic notebook (question 1) than in the course components it supported (question 2, 3, 4). A possible reason students may have reported that the notebook was of "little" or "no" help may have been because they did not know how to use it to its full potential. This could be improved by incorporating a standardized template for students to follow. Additionally, students and instructors should consider the electronic notebook as not only a platform for submission but also a space for collaborative learning.

Another barrier to perceived value reported by students was technical limitations. A student noted:

> *It did not help much during my class. It mostly had problems syncing to our worksheets, and half of the time my app crashed on my phone, laptop, and tablet when I was trying to access previous worksheets.*

These technical barriers can lead to frustration for students that not only directly impact their learning engagement but also cause decreased motivation to participate. The student may wish to refrain from coming to class or actively participating under the assumption that the electronic notebooks would not work. This could contribute to the explanation of the lower value placed on attending class meetings as reported in the survey. As instructors improve their competency with the electronic notebook, they can assist students by troubleshooting issues they come across such as synching or repeated crashing as mentioned above by one of the students. Flexibility (e.g. extending deadlines when technical issues impact student's ability to submit the material on time) can also improve the perceived value of the electronic notebook and improve/provide significance to attendance.

Conclusion

Students valued what the electronic notebook fostered for them (i.e., collaboration, organization). However, they seemed to still hold an overall negative opinion of the electronic notebook itself. This could be explained by the learning curve and technical issues that interfere with their learning. We offer a few suggestions to mitigate this apparent limitation including to implement an orientation and training process to cover the initial learning curve and using standardized templates and language for documents and activities. Additionally, instructors can emphasize the purpose of using the notebook and the benefits it offers.

Based on the current findings, electronic notebooks offer distinct benefits in learning engagement and social interactions. For example, it was found that students valued going over problems with their group and noted that the electronic notebook helped facilitate this collaboration. Given this, instructors should consider promoting the notebook's potential for collaborative learning by encouraging students to share their work and engage in discussions to enhance their learning experiences. Secondly, it was found that the students valued the electronic notebook for its utility in efficiently organizing the materials they used in class, leading to increased learning engagement. Therefore, it can be recommended that the electronic notebook should be integrated into the course design through means such as aligning its format and use with the course objectives and streamlining course activities to maximize the organizing ability of the students.

We acknowledge that the electronic notebook is one of many available tools that can be used to facilitate the engagement and social interactions that students valued. As with any tool, addressing varied perceptions of the tool's value requires ongoing assessment and adaptation based on student feedback, creating channels for regular feedback, and demonstrating its impact on learning outcomes. Continuous research into electronic notebooks and their impact on learning is essential, allowing educators to refine their use and ensure they remain a valuable tool in the classroom. By addressing these barriers and promoting collaborative features, educators can maximize the electronic notebook's benefits and improve the overall learning experience for the students.

Acknowledgements

We would like to thank the students who participated in the survey.

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