JOURNAL OF CHEMICAL EDUCATION

Article

pubs.acs.org/jchemeduc

Student-Led Development of an Interactive and Free Biochemical Methods eBook

Alyssa C. Hill,[†] Logan M. Nickels,[‡] and Paul A. Sims*[,‡]

[†]Department of Microbiology and Plant Biology, University of Oklahoma, Norman, Oklahoma 73019, United States

[‡]Department of Chemistry and Biochemistry, University of Oklahoma, Norman, Oklahoma 73019, United States

Supporting Information

ABSTRACT: An approach to create an interactive and inexpensive electronic book (eBook) for an undergraduate biochemistry laboratory course is presented. This approach featured the involvement of an undergraduate student in the lead role of designing and developing the eBook using Apple's iBooks Author application. The eBook, entitled *Introduction to Biochemical Methods*, contains original, interactive course content, including laboratory protocols, lecture slides, images, videos, figures, and quizzes. Access to the book content was expanded through the creation of a Web-based version of the book. User access analytics on both the eBook and the Web site, along with student survey data related to the usage of and attitudes toward the eBook, also are presented. Although the *Introduction to Biochemical Methods* eBook was developed specifically for use in a particular course, adaptation of its content for use in other classrooms is invited, and educators are encouraged to adopt a similar approach (i.e., involving their students) in developing eBooks for courses at their learning institutions. The immersive nature of the design and development process provided significant learning experiences for the student who led the development of the eBook.

KEYWORDS: *Upper-Division Undergraduate, Biochemistry, Multimedia-Based Learning, Student-Centered Learning*

Undergraduate laboratory-based courses can "evolve" over time, especially if they are taught repeatedly by the same instructor or small group of instructors. Protocols get tweaked, experiments get overhauled or removed and new ones take their place, and additional explanatory handouts and lecture slides get added. These materials often end up appended to the course site on the particular university's learning management system, and students have to pay careful attention to make sure they are downloading and reading (and possibly printing) the correct materials for the current topic and laboratory investigation. At this point, a more efficient and streamlined information delivery system would possibly help, but the time to develop such a system can be hard to find. Potential help is available, however, and it could be staring at the instructor.

Undergraduate students who show a strong interest in the learning process can obtain relevant experience in this area by participating in the design and development of instructional materials. This participation can take many forms, but one form that is well suited for student involvement (and that would help with the above-mentioned streamlining of course material) includes the creation of interactive electronic books (eBooks). Interactive eBooks hold promise as instructional aids because they allow for content customization, and they allow for the use of a wider range of materials. But to avoid the possibility of having such an activity turn into a mindless exercise in copying instructor-created material and pasting into an eBook, the students who help in this endeavor should be encouraged to be creative, to take charge of the design and development process, and to add new material to complement the instructor-created material.

The availability of eBook authoring programs such as Apple's iBooks Author has made it relatively easy for educators (and their students) to expand the pool of quality books by building their own eBooks and sharing them with others. For example, iBooks Author was used to develop an electronic textbook entitled *Biochemistry Free and Easy*, which is aimed at helping undergraduate students grasp the fundamentals of biochemistry in an interactive format.[1] The authors of this eBook credit the work of two students who were paid to produce the artwork.[1] This book is available to download for free through Apple iBooks.[1] Similarly, iBooks Author also was used to develop an electronic laboratory manual for undergraduates in the organic chemistry course series at this university, and a number of graduate students assisted in this endeavor.[2] This book also is available to download for free via iBooks.[2]

The above examples are but two of many where students helped to create instructional materials. Other examples include student-co-written data simulation and reduction programs;[3]

Received: July 13, 2015
Revised: March 7, 2016

DOI: 10.1021/acs.jchemed.5b00572
J. Chem. Educ. XXXX, XXX, XXX−XXX

a student-generated database for the physical chemistry laboratory;[4] student-generated computer models for studying bioenergetics;[5] student-written multiple choice questions;[6] how-to videos for using laboratory equipment;[7] and a student-designed green chemistry laboratory project for organic chemistry.[8]

The possibility of creating an eBook was discussed with an undergraduate student who had expressed interest in working on such a project as part of an Honors Independent Study, and the resulting eBook, entitled *Introduction to Biochemical Methods*, was made available for students in the undergraduate laboratory-based course of the same name (hereafter referred to as the Methods course). The student developer encountered a number of challenges throughout the design and development of the eBook, and thus, this activity provided a significant learning experience. Access to the book content was expanded through the creation of a Web-based version of the eBook, which was accomplished through collaboration with the university's library personnel. Reported herein is an account of this overall process, along with user-access analytics for the eBook and corresponding Web site. In addition, the results of surveys that queried student usage of and attitudes toward the eBook also are included.

METHODS AND MATERIALS

Book Organization and Content

To create the eBook, the student used the iBooks Author application. This easy-to-use application allows for customization of Apple-designed book templates that prompt placement of assets including text, images, videos, and interactive elements known as widgets. Consistent with the emphasis of the Methods course, the student organized the eBook by laboratory session such that each of the 14 chapters was dedicated to a specific laboratory topic. The organization of chapters and chapter learning objectives are provided in the Supporting Information.

The student began each chapter with a brief introduction to the major themes and concepts that were integral to the accompanying laboratory investigation. These introductions were followed by the learning objectives, and then, typically, by lecture notes (embedded as Keynote presentations) and supplementary handouts that had been prepared by the instructor. The student also added original material such as demonstration videos, which she and a graduate teaching assistant scripted, filmed, edited, and captioned on their own. (This is but one of many examples of the learning opportunities afforded by this project.) The final section of each chapter contains a list of materials with linked safety data sheets (SDS), the objective(s) for the lab session, and the laboratory protocol. In addition, photos, built-in note taking, highlighting, and scientific calculator applications were added, as were interactive quizzes to help students assess their understanding of the specific concepts covered in each lab. Once again, these latter features were added by the student developer. Throughout the process of creating the eBook, the student reviewed newly added material with the instructor to ensure the accuracy of the material.[9]

Book Design

Developing the book aesthetic also was a creative process. The student chose a visual design model that considered the goals, context, visual approach, communication functions, and principles of psychological instructional events to inform her decisions about the book's treatment, individual graphics, and layout.[10] Because the electronic book is a highly visual medium, the major design consideration was to direct students' attention toward information that advanced instructional goals while eliminating distractions and avoiding the activation of inappropriate prior knowledge.[10] For example, only functional, rather than decorative, graphics were incorporated. The student also consulted with graphic designers at this university's Center for Teaching Excellence; these designers weighed in on the overall look and feel of the book and helped develop ideas for the book cover, chapter banners, and asset placement, although the student was allowed to have final say on the design of the finished product.

Book Publication and Web Site Development

With the help of the Center for Teaching Excellence at this university, the *Introduction to Biochemical Methods* eBook was published on March 17, 2014 via Apple iTunes.[11] The book was made freely available for download via Apple iBooks.[11] For those who are interested, a discussion of some of the special considerations (e.g., copyright, Americans with Disabilities Act compliance) that should be addressed prior to creating an eBook for a course is provided in the Supporting Information.

eBooks developed with iBooks Author and published via iTunes can be downloaded and viewed on Apple devices only. Furthermore, restrictions on file format conversion make accessing the native book content on Android- and Windows-based tablets difficult. To expand access to book content, collaboration with this university's library personnel allowed development of a Web site that preserves the structure and much of the interactivity of the *Introduction to Biochemical Methods* eBook. The Web site was developed using Adobe Dreamweaver, SlideShare, YouTube, and Google Forms. The site went live on September 3, 2014.[12]

To further increase accessibility to the eBook content, the videos included in the book and on the Web site were hosted on a YouTube channel.[13] Placement of the videos on YouTube allows users to search for and be referred to videos outside of the eBook and Web site environments.

Survey Design

To establish student usage of and attitudes toward the *Introduction to Biochemical Methods* eBook, the student developer underwent the necessary training specified by the Institutional Review Board (IRB), and then she used Qualtrics Online Survey Software to design Web-based surveys. After obtaining IRB approval to use the surveys,[14] the student developer administered the surveys to students who were enrolled in the Methods course. A prebook survey was administered to students enrolled in the course during the spring 2014 semester, prior to the introduction of the eBook. The postbook survey was administered to students enrolled in the course during the same semester but following the introduction of the eBook, as well as to students enrolled in the summer and fall 2014 semesters who had access to the book from the start of each semester.

Students were informed about the survey both via e-mail and in class, and for each survey, students were given approximately 2 weeks to respond.[15] In accordance with research on improving response rates to online surveys,[16] surveys were kept brief (i.e., each survey consisted of approximately 20 questions and took about 10 min to complete), reminder e-mails were sent, faculty were encouraged to give regular reminders in class, and students were assured that their

DOI: 10.1021/acs.jchemed.5b00572
J. Chem. Educ. XXXX, XXX, XXX−XXX

responses would be used to help improve the class. Copies of the surveys are included in the Supporting Information.

Use of the eBook in Class

The Methods class has both a lecture and laboratory component. The lectures are taught by the instructor and are intended to provide the theoretical background necessary to understand and appreciate the corresponding laboratory investigations. In addition, the lecture also provides practical information as well such as how to fit experimental data to theoretical expressions using a spreadsheet. Weekly homework assignments are designed to reinforce concepts introduced in lecture, and although a textbook is recommended, none is required. The laboratory investigations are taught by the teaching assistants, and students are required to complete a prelab assignment prior to starting each experiment. The prelab is written in a lab notebook, and it contains a flowchart that outlines the experimental steps and a condensed version of the protocol that students will use to complete the laboratory investigation.

The goal of creating the eBook was to consolidate lecture and laboratory material so that students could more easily access the relevant lecture slides, explanatory handouts, laboratory protocols, and, thanks to the student developer, newly created explanatory videos. This streamlined organization obviated the need for students to access the learning management system and then search for (and download and print) the various materials prior to the start of each class or lab. In addition, the interactive nature of the eBook was expected to facilitate the completion of weekly homework and prelab assignments because the text is easily navigable and searchable, and thus relevant information is easier to find.

RESULTS AND DISCUSSION

Access Analytics for eBook Users

Sales and Trends data retrieved from Apple iTunes Connect indicate that the eBook *Introduction to Biochemical Methods* had 659 unique downloads from the time of its publication to Apple iBooks on March 17, 2014 to March 1, 2015. Downloads of the book were not limited to the United States and are broken down by territory in Figure 1. (Rounding of data in Figure 1, and in the discussion below concerning other analytics data led, in some instances, to totals that slightly exceed 100%.) Interestingly, over 25% of the observed downloads were in Japan.

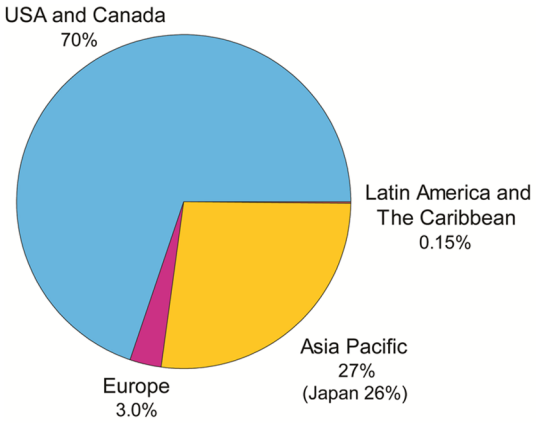

Figure 1. Downloads of the *Introduction to Biochemical Methods* eBook from Apple iBooks by territory.

For all territories, spikes were seen in May and September 2014, with a subsequent drop-off in downloads through March 2015. The sharp rises in the number of downloads for May and September 2014 could potentially correspond to students downloading the book at the beginning of the summer and fall semesters, respectively. Interestingly, downloads in Japan also followed this trend, with sharp rises in the number of downloads for May and September 2014. Thus, the eBook may have been used for a course taught in Japan, but analytics data cannot be resolved enough to follow up on this speculation.

Access Analytics for Web Site Users

The Introduction to Biochemical Methods Web site went live on September 3, 2014. Google Analytics data indicate that from this date to March 23, 2015, there were 2382 unique sessions by 937 users. Of those sessions, 88% were by desktop, 6.5% by tablet, and 5.0% by mobile. Combining mobile and tablet sessions together (total: 274 sessions), the operating system that most accessed the Web site was Apple iOS at 66%. Android operating systems accounted for 19% of all mobile and tablet sessions, and Windows operating systems accounted for 13%. Most users accessed the Web site from the United States, which accounted for 87% of all sessions. Of those sessions, 85% were in Oklahoma. Collectively, these data suggest that the Introduction to Biochemical Methods Web site serves a different purpose than originally intended, i.e., rather than expanding access to students with Android- and Windows-based tablets, the Web site caters to students who prefer to access the eBook content by desktop and by phone.

Access Analytics for YouTube Users

YouTube analytics data from March 17, 2014 to March 1, 2015 indicate that all videos on the dedicated YouTube channel had a total of 604 views. This view count includes videos watched on the YouTube Web site and within the Introduction to Biochemical Methods Web site, but not within the *Introduction to Biochemical Methods* eBook. No data are available regarding video views from within the eBook. The data further indicate that most users accessed the videos via external searches (29% of views) and YouTube searches (28% of views), rather than from unknown−embedded players (17% of views), which primarily includes the Introduction to Biochemical Methods Web site. Other traffic sources such as suggested videos, direct or unknown, external apps, YouTube channels, browse features, and playlists make up the remaining 29% of views.

The most viewed video was a theoretical one that discussed a graphical approach to deriving the rate equation when an uncompetitive inhibitor is present (61% of views), followed by demonstration videos that discussed how to use a centrifuge (11% of views), spectrophotometer (10% of views), and pipet (6% of views). The remaining videos each accounted for 5% or less of the views. Top geographies included the United States (42% of views), India (11% of views), and Canada (8% of views). The remaining countries each accounted for 4% or less of the views. Top devices included computers (85% of views), mobile phones (8% of views), and tablets (6% of views). Collectively, the above data suggest that the primary goal of hosting videos on the dedicated YouTube channel, which was to expand access to book content outside of the *Introduction to Biochemical Methods* eBook and Web site environments, was met.

Surveys

A total of 43 out of 95 students (45%) completed the spring 2014 prebook survey, 11 out of 95 (12%) completed the spring

DOI: 10.1021/acs.jchemed.5b00572
J. Chem. Educ. XXXX, XXX, XXX−XXX

2014 postbook survey, 15 out of 26 (58%) completed the summer 2014 postbook survey, and 17 out of 80 (21%) completed the fall 2014 postbook survey. Despite efforts to improve response rates, only the spring 2014 prebook and summer 2014 postbook surveys were sufficient for an 80% confidence level with 10% sampling error, and none was sufficient for a more conservative 95% confidence level with 3% sampling error.[16] Thus, survey data obtained in the spring and fall 2014 postbook surveys may not be representative of student usage and attitudes for the population of students enrolled in the course during those semesters.

Usage of the eBook

The proportion of survey respondents who indicated that they used the *Introduction to Biochemical Methods* eBook was 4 out of 11 (36%) for the spring 2014 postbook survey, 13 out of 15 (87%) for the summer 2014 postbook survey, and 13 of 17 (76%) for the fall 2014 postbook survey. Among respondents who indicated that they had used the eBook, laboratory protocols were selected as the most accessed element in the book for all three semesters, followed by lecture slides and then by screencasts and demonstration videos.

Attitudes Toward eBook

Of those students who used the *Introduction to Biochemical Methods* eBook, 3 of 4 (75%), 11 of 13 (85%), and 9 of 13 (69%) reported liking it (i.e., rated it a 4 or 5 on a scale from 1 to 5) in the spring, summer, and fall semester surveys, respectively. Compared with the prebook surveys, students did not report that accessing course materials was easier, nor did they report that they liked the course materials more, in the postbook surveys.

Comments from free-response survey questions about the *Introduction to Biochemical Methods* eBook highlight some of the reasons students liked the book and provide insight into ways in which the book may be improved in future versions. Some representative student comments are given below.

- Reasons students liked the book:
  - "I liked the interactive tools in the iBook such as the videos as well as quizzes. The ability to open different modules while using the iBook made it more interactive and beneficial."
  - "The iBook is nice because it is extremely helpful, it isn't an actual book made out of paper (environmentally-sound), and it is free (economically-sound)."
  - "Free, easy to access, interactive."
  - "It was an easily accessible resource while I was on-the-go."
- Student suggestions for improving the book:
  - "Make the iBook available for other devices and regular computers."
  - "Try to add more videos to the iBook so people can better prepare for lab. It would help people that are visual learners."
  - "My only complaint about the iBook is that on iPad you can only view it if the iPad is horizontally oriented."

During subsequent semesters, student feedback will be sought for improving future versions of the eBook, and analytics will be monitored for the eBook and Web site to determine how access to the content can best be expanded and modified.

Utility of the eBook

Use of the eBook, and, later, of the companion Web site, were not expected to lead to dramatic learning gains because much of the core material such as lecture slides, explanatory handouts, and laboratory handouts had been in use and available prior to the development of the eBook. This material remained available on the course site within the learning management system, and thus students could continue to access this material in the usual manner. Indeed, prior to the development of the Web site, that is what students who did not have an iPad did. The new material in the eBook (e.g., explanatory and demonstration videos, interactive widgets and quizzes) was expected to complement existing material but not necessarily lead to noticeable learning gains. Instead, the expectation was that students would find the experience of using the eBook to be more enjoyable and efficient than the previous method of accessing course materials. The above-mentioned survey data, though limited, suggest that students enjoy using the eBook, but at this point they do not feel that using it provides a significant advantage in terms of accessing course information.

Benefit to the Student Developer

As noted, one undergraduate student was primarily responsible for the design and development of the eBook. A striking feature of this process was how immersive it was in terms of learning opportunities, and a summary of some of the major benefits derived by the student developer is presented in Table 1. For a student who shows a keen interest in the learning process and who is considering a career in academia, participation in such a multifaceted project can provide valuable experience. And, although this work was done by one student, there is no reason why additional students could not work together on such a project.

Table 1. Overview of Immersive Learning Activities (and Associated Outcomes) in Which the Student Developer Engaged during the Design, Development, and Implementation of the eBook

Learning Activity	Outcome
Using iBooks Author to create the eBook	Finished eBook
Scripting/filming/editing tutorial videos	Embedded videos in eBook
Ethics/IRB training	IRB approval
Designing, writing, and implementing surveys using Qualtrics software	Completed surveys
Consulting with library personnel to help develop the Web site version of the eBook	Functioning Web site version of eBook
Working with this university's Center for Teaching Excellence to design the aesthetic of the eBook	Professional-looking eBook
Poster presentation and manuscript preparation	Experience presenting orally and in writing

SUMMARY

An undergraduate student led the development of an interactive and free eBook for use in an undergraduate biochemical methods course. The student created the eBook using Apple's iBooks Author software, and the eBook is available to download via Apple iBooks. Access to the eBook's content was expanded through the development of a Web-based version of the eBook; this Web version preserved much of the structure and interactivity of the eBook. In addition, videos from both the eBook and Web site were hosted on a

DOI: 10.1021/acs.jchemed.5b00572
J. Chem. Educ. XXXX, XXX, XXX−XXX

YouTube channel. Survey data revealed that students who used the eBook appreciated that it is interactive, environmentally friendly, and available at no cost. Analytics data revealed that the book content is frequently and widely accessed both on the Web site and on YouTube. Finally (and notably), the many steps required to design and develop the eBook were replete with learning possibilities, and the student who led this project gained many valuable new skills. Accordingly, the authors invite adaptation of eBook content for use in other classrooms, and, more importantly, encourage educators to adopt the described workflow and involvement of students in the creation of open, interactive educational materials such as eBooks.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00572.

(i) A table that lists the eBook chapters and learning objectives, (ii) a discussion of some of the special considerations that one may wish to address before creating an eBook for a course, and (iii) copies of the pre- and postbook surveys described in the manuscript (PDF)

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: psims@ou.edu.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

The authors acknowledge the Alternative Textbook Initiative at the University of Oklahoma for funding this project. They also thank Stacy Zemke from the University of Oklahoma Libraries for supporting this project, and Cody Taylor from the University of Oklahoma Libraries for developing the Web-based version of the book. Additionally, the authors thank William "Biff" Farrell in the Center for Teaching Excellence (CTE) at the University of Oklahoma for his assistance in captioning videos and for helping finalize and publish the eBook. The authors also thank Stephanie Shilling for her assistance in creating chapter banner illustrations and designing the cover of the book. Finally, the authors thank Dan Bamper for his early assistance with iBooks Author, and Cal Butcher for providing helpful comments about filming the videos.

■ REFERENCES

(1) Ahern, K.; Rajagopal, I. *Biochemistry Free and Easy*; DaVinci Press, 2012. This eBook can be downloaded at: https://itunes.apple.com/us/book/biochemistry-free-and-easy/id548161352?mt=13 (accessed Jan 2016).

(2) Morvant, M. C.; Halterman, R. L. *Organic Chemistry Laboratory Manual*; The University of Oklahoma's Center for Teaching Excellence, 2013. This eBook can be downloaded at: https://itunes.apple.com/us/book/organic-chemistry-laboratory/id615613893?mt=13 (accessed Jan 2016).

(3) Johnson, K. J. Simulation and Data Reduction Programs. *J. Chem. Educ.* **1980**, *57*, 406.

(4) Wood, J. A. A Student-Generated Database for the Physical Chemistry Laboratory. *J. Chem. Educ.* **1988**, *65*, 343−344.

(5) Howland, J. L. A Course in Bioenergetics Based upon Student-Generated Computer Models. *Biochem. Educ.* **1994**, *22*, 198−198.

(6) Bottomley, S.; Denny, P. A Participatory Learning Approach to Biochemistry Using Student Authored and Evaluated Multiple-Choice Questions. *Biochem. Mol. Biol. Educ.* **2011**, *39*, 352−361.

(7) Benedict, L.; Pence, H. E. Teaching Chemistry Using Student-Created Videos and Photo Blogs Accessed with Smartphones and Two-Dimensional Barcodes. *J. Chem. Educ.* **2012**, *89*, 492−496.

(8) Graham, K. J.; Jones, T. N.; Schaller, C. P.; McIntee, E. J. Implementing a Student-Designed Green Chemistry Laboratory Project in Organic Chemistry. *J. Chem. Educ.* **2014**, *91*, 1895−1900.

(9) Remaining errors that are identified will be corrected in an updated version of the eBook and Web site.

(10) Clark, R. C.; Lyons, C. C. *Graphics for Learning: Proven Guidelines for Planning, Designing, and Evaluating Visuals in Training Materials*, 2nd ed.; Pfeiffer essential resources for training and HR professionals; Pfeiffer: San Francisco, 2011.

(11) Hill, A. C.; Nickels, L. M.; Sims, P. A. *Introduction to Biochemical Methods*; Center for Teaching Excellence - The University of Oklahoma, 2014. This eBook can be downloaded at: https://itunes.apple.com/us/book/introduction-to-biochemical/id835187266?mt=13 (accessed Jan 2016).

(12) The Website can be viewed at: www.ou.edu/OpenEducation/ou-resources/biochemical-methods-v2 (accessed Jan 2016).

(13) The YouTube channel can be viewed at: https://www.youtube.com/channel/UCNP3gF5V7IMlBWllDaQv0GA (accessed Jan 2016).

(14) IRB Number 3981. February 26, 2014.

(15) Dommeyer, C. J.; Baum, P.; Hanna, R. W.; Chapman, K. S. Gathering Faculty Teaching Evaluations by In-class and Online Surveys: Their Effects on Response Rates and Evaluations. *Assess. Eval. High. Educ.* **2004**, *29*, 611−623.

(16) Nulty, D. D. The Adequacy of Response Rates to Online and Paper Surveys: What Can Be Done? *Assess. Eval. High. Educ.* **2008**, *33*, 301−314.

DOI: 10.1021/acs.jchemed.5b00572
J. Chem. Educ. XXXX, XXX, XXX−XXX