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Student and Instructor Generated Open Educational Resources Compare Favorably to a Traditional Textbook

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Abstract

Open Educational Resources (OER) are freely available materials that can be used in courses and modified by instructors. We developed an online OER silviculture textbook (OT). Some sections of OT were developed by the instructor, whereas others were developed by students enrolled in a silviculture course and subsequently edited by the instructor. As a preliminary examination of the effectiveness and student preference of OT, we administered a knowledge assessment and survey to both freshman and junior-level forestry students. We compared OT to a highly respected textbook in the field, *The Practice of Silviculture, 9th Edition* (Smith et al. 1997). Based on this study, both resources performed similarly and were similarly preferred by students. Although there are a number of limitations to this preliminary study (small sample size, only conducted at a single university, formatting both sources as paper copies) and to OER (time-consuming to create, lack of funding, lack of peer review), our results support further exploration of OER for use in forestry courses.

Keywords: open educational resources, OER, silviculture, textbook, pedagogy, scholarship of teaching and learning

Open Education Resources (OER) are teaching materials that are made publicly available to be accessed and modified by instructors and students without making users pay textbook, royalty, or licensing fees (Butcher 2015). Textbooks are an integral part of almost every classroom. However, with constant advancements in technology, textbooks often need revisions and costly republications every few years (Ohles 1953), although we note that newer trends in textbook formats (e-books, electronic supplements) have been reducing costs in some cases. Utilizing OER alone or in combination with traditional textbooks can aid instructors in diversifying content sources and material delivery methods (Hendricks et al. 2017), providing many advantages and making education more accessible by lowering coursework costs (Hilton 2016, Martin et al. 2017, McMutrie 2017). For example, because OER sources can be edited, they may be adapted to specific activities an instructor plans in the classroom, such as small group work solving problems or discussing case studies. In natural resources fields, they can be made region-specific to better suit the interests and experiences of students. The disadvantages of OER include availability of content for a particular subject matter, funding to create materials, and ensuring quality of work, including peer review (Allen and Seaman 2016, COL 2017). However, there is increasing interest in developing solutions to these issues, such as transitioning from early efforts in OER founded by charitable foundations to a more sustainable government-funded

Management and Policy Implications

Increasingly more information is becoming freely available online. Coupled with increased costs of education, there is great interest in OER that are freely available, often in online form, for use in college courses. Our study supports that OER can be developed by both faculty and undergraduate students that are as effective and similarly preferred by students as a more traditional peer-reviewed textbook. This implies that as more effort is expended on creating OER, more information relevant to silviculture and other forest management topics will be freely available to students, land managers, landowners, and policymakers. However, OER present challenges such as the need for peer-review and limited resources available for creation and updating. Future discussions on the role of the Society of American Foresters' involvement with OER for forestry may be an avenue where our professional society can improve forestry education.

model (Stacey 2013). Recent studies show that the use of OER compared to traditional textbooks results in similar or better learning outcomes while saving students money and being positively regarded by both students and faculty (Hilton et al. 2014, Fischer et al. 2015, Hilton 2016, Williamson et al. 2016, Hendricks et al. 2017, Martin et al. 2017). However, none of these studies are in disciplines related to natural-resource management.

OER materials are not limited to textbooks, but can also include videos, curriculum worksheets, educational programs, curriculum maps, podcasts, and any other forms of teaching material available (Butcher 2015). Downes (2007) built upon previous work (Johnstone 2005, Hylén 2006) to enumerate the types of resources that might qualify as OER such as open courseware and content, open software tools, open material for e-learning, capacity building of faculty and staff, repositories of learning objects, and free educational sources. Although these resources are free to be used by the public, creators of OER do include mechanisms to protect the rights of the content developer (Butcher 2015). Although material typically is free to access and modify, creators still receive credit for their work, often with license structures similar to Creative Commons BY, BY-SA, BY-NC, or BY-NC-SA (Creative_Commons 2018).

One of the biggest benefits of OER is that the curriculum is completely customizable so that instructors can create materials that directly support program- and course-level learning goals and objectives (Williamson et al. 2016). Additionally, the use of OER dramatically cuts the costs of learning materials for a class, which is important to many students, especially college students who often face difficulties in affording the required textbooks and learning materials for their classes on top of tuition and fees (Allen and Seaman 2016, Gose 2017, Martin et al. 2017). As tuition and fees continue a decades-long trend of increasing, the affordability of college is increasingly drawn into question (Seltzer 2017). OER resources are one potential area of student cost-savings within the direct control of faculty. This provides an equal opportunity for all of the students to have access to needed materials, allowing for better chances of academic success. OER can also be easily designed or selected to better suit the number and length of the specific class sessions being taught (Hook and Kahn 1990, Martin et al. 2017).

Before OER can become more commonly used in higher education, there are numerous challenges to overcome. One of the primary impediments in the developed world, where Internet access is widely available and students are proficient with required technologies (D'Antoni 2009, Allen and Seaman 2016, COL 2017), is related to the cost of creating OER. Although one of the main benefits of OER is a lower cost to students, there is no revenue generated by OER to provide funding to content developers to incentivize and support the creation of OER (Hylén 2006). It is possible that public funding and research incentives from private institutions could compensate for development (Smith and Casserly 2006, COL 2017), although these potential sources of funding are not currently widespread in North America.

The goals of this preliminary study were twofold. First, we examined the use of part of an OER textbook in both introductory and junior-level forestry courses to examine if trends observed in other fields (business, computer science, physics) regarding favorable student perceptions and positive learning outcomes would be observed in a forestry curriculum. Second, we sought to examine whether an OER textbook could be produced by including undergraduate student peers in the development to help to lower the cost of content creation while furthering their learning. The hope is that this will be the first step in a longer-term series of studies relating to use of OER in forestry. Our specific hypotheses were:

1. An OER silviculture textbook created by faculty and undergraduate student peers will impart the same knowledge gains as a traditional textbook.
2. Preference for an OER silviculture text created by faculty and undergraduate students and a traditional text will be equal.
3. Both the OER and traditional textbooks will perform similarly for both higher and lower GPA students.

Methods

The Practice of Silviculture, 9th Edition (Smith et al. 1997) is one of several highly regarded (Bowersox 1997) classic textbooks used in undergraduate forestry courses throughout North America (abbreviated PS hereafter). The 1st Edition was published in 1921 by Hawley (Hawley 1921). We selected chapter 14 entitled "Double-Cohort Pure Stands Regenerated by Partial Cutting," pages 347–363, for this study. This chapter describes the seed-tree and shelterwood regeneration methods. We compared this traditional textbook chapter to OER resources generated by the instructor and peers and posted to the Stephen F. Austin State University (SFA) Silviculture website (Stovall 2018). Two separate chapters were created: the first focused on only the seed-tree regeneration method authored by the course instructor (Stovall 2017); the second focused on the shelterwood regeneration method, and written for extra credit by two undergraduate students enrolled in FOR 347: Silviculture during the fall 2016 semester (Welford et al. 2018). This chapter was subsequently edited by the course instructor. Both these online textbook (hereafter abbreviated OT) chapters were taken offline during the entirety of the fall 2017 semester when this study was conducted to prevent students from being exposed to the material prior to the study.

We developed a closed-book, individual-effort knowledge test to be administered to students as a survey (IRB Case # AY2018-1020) prior to completing the reading (pretest) and following their completion of the reading (post-test). Students were allowed to complete these tests and readings in their own time, but were assigned a deadline later that week. This assignment was completed prior to any classroom or lab coverage specifically focused on these topics in both classes. The 10-item knowledge test was a combination of multiple-choice and multiple-selection formats. Items were carefully selected to ensure that answers were similarly difficult to find in both PS and OT. The items were reviewed and edited for accuracy by two professors with subject-matter expertise in silviculture. Ten additional items were added to the post-test to assess student preference for the readings using a five-point agree/disagree scale. Several of these were inverse pairs for later quality control of responses. Three open-ended items asked students to describe what they preferred most and least about the reading materials, with one question asking for suggestions to improve the reading materials.

Both readings were typed and formatted with the same fonts, and figures were reproduced as in the original source, although in black and white rather than color. We acknowledge this altered some of the features that impact the efficacy of both sources (e.g., electronic versus print material), but our primary goal in this study was to test how the content in a novel and wholly untested course aid (OT) performed relative to the traditional textbook (PS). Any identifying information regarding the authors or sources was removed, and both readings were of similar length (7,935 words for OT, 8,156 words for PS). The FOR 347 students were stratified by GPA and then randomly assigned to one reading. Stratification was completed by ranking the class from high to low GPA, and then creating small, even-numbered groups in approximately 0.5 GPA point increments within which the two readings were randomly assigned in equal proportion. The FOR 111 students were randomly assigned to one reading without prior stratification, as no accurate GPA information was yet available for first-semester students that made up the majority of this population. Readings were provided as paper copies, so the format and method of delivery would not bias the results. The FOR 347 students had previously completed at least one reading from each source, potentially helping them acclimate to the differing styles for whichever source they were randomly assigned. Further, the reading assignment was given within the first 3 weeks of a 17-week semester, likely before they had formed many significant habits or opinions relating to either source.

Reliability analysis was completed for all items in the readability and enjoyment section using SPSS version 23 (IBM, Armonk, New York) using Cronbach's α to determine internal reliability of each section of responses. Knowledge assessment and preference items were analyzed using SAS 9.2 (SAS Institute, Cary, NC). A completely randomized experimental design with a two-by-two factorial structure was used. The main effects were class level (FOR 111, FOR 347) and assigned reading (OT, PS). Pretest score, post-test score, and their difference were all normally distributed and had homogeneous variances among all treatment combinations, so no transformations were required. These data were analyzed using PROC GLM. For the five-point agree/disagree scale data from the preference items, a multinomial model with a cumulative logistic link function was assumed and run using PROC GLIMMIX. Simple linear regressions were performed using PROC REG for the FOR 347 students with GPA as the independent variable and the change between pretest and post-test scores as the dependent variable.

For the open-ended responses, data were systematically analyzed to identify themes and coded and reviewed for overarching concepts (Glaser and Strauss 2017). The two readings (OT and PS) were coded separately and then compared to explore any possible differences in the student response for each of the items. The three open-ended questions were:

1. What did you like best about the reading?
2. What did you like least about the reading?
3. What suggestions do you have to improve the reading?

Results

A total of 59 pre- and post-tests were completed. Reliability analysis for all items in the readability and enjoyment section resulted in a Cronbach α of 0.791 (n = 59). Two question sets were compared; Q1 and Q5 were inverse questions, as were Q2 and Q6. After eliminating four responses for inconsistent response to Q1 and Q5, the Cronbach α was 0.864 (n = 55), a slight improvement from 0.713 (n = 59). After eliminating seven responses for inconsistent response to Q2 and Q6, the Cronbach α was 0.830 (n = 52), an improvement from 0.516 (n = 59). When removing these two sets of responses, the final Cronbach α for this item set was 0.807 (n = 50, FOR 111 n = 29, FOR 347 n = 21), a good indicator of internal consistency. Essentially, we removed nine surveys from respondents who did not appear to earnestly attempt the tests.

The knowledge assessment was intentionally designed to be very difficult. The pretest means were 3.3 and 4.6 out of a maximum of 10 for the FOR 111 and FOR 347 students, respectively (P < .05, Table 1). As would be expected, the junior-level FOR 347 students outperformed the freshman-level FOR 111 students on the pretest (Table 1). There were no differences between classes or readings on the post-test results (4.8/10), or on the level of improvement between the pre- and post-tests (1.0 point, Table 1).

Based on the readability and enjoyment survey, students were neutral to slightly positive about both readings (Table 2). They reported being neutral to slightly positive about wanting to learn more (μ = 3.3) and wanting to recommend both readings to a friend (μ = 3.6). The FOR 111 students agreed slightly more that PS was well written relative to OT (μ = 4.0 versus 3.6, respectively), although the FOR 347 students felt more strongly that OT was well written relative to PS (μ = 4.3 versus 3.5, respectively). Overall, the students were neutral to positive that the readings were easy to understand (μ = 3.4), and at an appropriate level for their understanding (μ = 3.8). The FOR 347 students

Table 1. Knowledge assessment of an open educational resource online textbook (Stephen F. Austin State University Silviculture Online Textbook, OT) compared to a traditional print textbook (Smith et al. 1997 Practice of Silviculture, PS).

		Pretest	Post-test	Change
P-values	Reading	0.774	0.299	0.480
	Class	0.005*	0.126	0.568
	r × c	0.809	0.297	0.293
FOR 111	OT	3.3 (0.4), 18	5.0 (0.4), 18	1.6 (0.6), 18
	PS	3.3 (0.5), 11	3.7 (0.7), 11	0.4 (0.7), 11
	OT & PS	3.3 (0.3), 29*	4.5 (0.4), 29	1.2 (0.5), 29
FOR 347	OT	4.7 (0.4), 10	5.2 (0.4), 10	0.5 (0.6), 10
	PS	4.5 (0.4), 11	5.2 (0.7), 11	0.8 (0.7), 11
	OT & PS	4.6 (0.3), 21*	5.2 (0.4), 21	0.7 (0.5), 21
FOR 111 & FOR 347	OT	3.8 (0.3), 28	5.1 (0.3), 28	1.2 (0.4), 28
	PS	3.9 (0.3), 22	4.5 (0.5), 22	0.6 (0.5), 22
Pooled	OT & PS	3.8 (0.2), 50	4.8 (0.3), 50*	1.0 (0.3), 50*

Note: Results are based on a survey of 50 students administered during the fall 2017 semester at Stephen F. Austin State University in two classes, FOR 111: Careers and Competencies in Forestry, and FOR 347: Silviculture. The maximum possible score was a 10.0. Notations are [mean (standard error), sample size].

*Values indicate significant P-values (P < .05) and the corresponding sample means that are relevant based on statistical results. All data are shown, even when not significant.

Table 2. Perceptions of an open educational resource online textbook (Stephen F. Austin State University Silviculture Online Textbook, OT) compared to a traditional print textbook (Smith et al. 1997 Practice of Silviculture, PS).

		I would recommend the reading to a friend who is a forestry major	The reading made me want to learn more about the subject	The reading was well written	The figures, photos, and illustrations confused me
P-values	Reading	0.900	0.309	0.415	0.383
	Class	0.328	0.853	0.844	0.906
	r × c	0.851	0.552	0.026*	0.163
FOR 111	OT	3.8 (0.3), 18	3.4 (0.2), 18	3.6 (0.2), 17*	1.9 (0.2), 18
	PS	3.7 (0.4), 11	3.2 (0.3), 11	4.0 (0.3), 11*	2.1 (0.5), 10
	OT & PS	3.8 (0.2), 29	3.3 (0.2), 29	3.7 (0.2), 28	2.0 (0.2), 28
FOR 347	OT	3.4 (0.4), 10	3.6 (0.3), 10	4.3 (0.3), 10*	1.6 (0.2), 10
	PS	3.5 (0.4), 11	3.2 (0.3), 11	3.5 (0.2), 11*	2.5 (0.4), 11
	OT & PS	3.4 (0.3), 21	3.4 (0.2), 21	3.9 (0.2), 21	2.0 (0.3), 21
FOR 111 &	OT	3.7 (0.2), 28	3.5 (0.2), 28	3.8 (0.2), 27	1.8 (0.1), 28
FOR 347	PS	3.6 (0.3), 22	3.2 (0.2), 22	3.8 (0.2), 22	2.3 (0.3), 21
Pooled	OT & PS	3.6 (0.2), 50*	3.3 (0.1), 50*	3.8 (0.1), 49	2.0 (0.2), 49*
		The reading was easy for me to understand	The reading was appropriate for my level of understanding of the topic	The reading was too simplistic for my level of understanding of the topic	The reading was too advanced for my level of understanding of the topic
P-values	Reading	0.196	0.215	0.712	0.011*
	Class	0.176	0.090	0.025*	0.007*
	r × c	0.218	0.195	0.936	0.375
FOR 111	OT	3.3 (0.2), 18	3.7 (0.2), 18	2.3 (0.2), 18	2.7 (0.2), 18
	PS	3.2 (0.4), 11	3.5 (0.4), 11	2.5 (0.4), 11	3.3 (0.4), 11
	OT & PS	3.2 (0.2), 29	3.6 (0.2), 29	2.4 (0.2), 29*	2.9 (0.2), 29*
FOR 347	OT	3.9 (0.3), 10	4.4 (0.2), 10	1.7 (0.2), 10	1.6 (0.2), 10
	PS	3.3 (0.3), 11	3.6 (0.4), 11	1.8 (0.2), 11	2.6 (0.4), 11
	OT & PS	3.6 (0.2), 21	4.0 (0.2), 21	1.8 (0.2), 21*	2.1 (0.2), 21*
FOR 111 &	OT	3.5 (0.2), 28	3.9 (0.1), 28	2.1 (0.2), 28	2.3 (0.2), 28*
FOR 347	PS	3.2 (0.2), 22	3.6 (0.3), 22	2.1 (0.2), 22	3.0 (0.3), 22*
Pooled	OT & PS	3.4 (0.1), 50*	3.8 (0.1), 50*	2.1 (0.1), 50	2.6 (0.2), 50

Note: Results are based on a survey of 50 students administered during the fall 2017 semester at Stephen F. Austin State University in two classes, FOR 111: Careers and Competencies in Forestry, and FOR 347: Silviculture. Data presented are based on a 5-point agree/disagree scale, where 1 is strongly disagree, and 5 is strongly agree. Notations are [mean (standard error), sample size].

*This values indicate significant *P*-values ($P < .05$) and the corresponding sample means that are relevant based on statistical results. All data are shown, even when not significant.

disagreed that the readings were too simplistic for them more so than the FOR 111 students (μ = 1.8 versus 2.4, respectively). The FOR 347 students also disagreed that both readings were too advanced, whereas the FOR 111 students were more neutral (μ = 2.1 versus 2.9, respectively). Students from both classes disagreed that OT was too advanced, but were neutral on PS for this item (μ = 2.3 versus 3.0, respectively).

When all the FOR 347 students were examined, there was no impact of GPA on their change in performance between the pre- and post-tests (P = .495, R^2 = .025, n = 21). However, for only the students assigned to OT, GPA and knowledge gain was inversely correlated (P = .004, R^2 = .66, n = 10, Figure 1). Students with lower GPAs generally improved the most, whereas students with higher GPAs actually performed more poorly on the post-test compared to their own pretest. Although it initially appeared there was a positive correlation between GPA and knowledge gain for the students assigned to PS, the correlation was nonsignificant and weak (P = .198, R^2 = .177, n = 11). GPA data were not available for the FOR 111 students, as many were first-semester freshmen.

$$\text{Knowledge gain} = 10.461 - 3.172\ (\text{GPA}) \quad (1)$$

The open-ended question responses to both textbook chapters were overall quite similar in nature, with a few notable exceptions. When asked what they liked best about the readings, students' responses for both textbook chapters included overall themes of satisfaction with the level of detail, structure, and format. Both readings also were similarly noted as being educational and informative. There was a stark distinction in the satisfaction with the images and graphs included in the OT textbook versus the PS textbook (nine responses to two responses respectively), even though both were provided to students in black and white rather than color. A few responses indicated that the OT textbook was direct, concise, and easy to read, whereas none of the students gave responses reflected under these themes for the PS textbook.

When asked what they liked least about each chapter, students' general thematic responses indicated that they found both textbook chapters could use more figures or better quality figures. Differences arose when students discussed the difficulty of the reading in terms of understanding. More students indicated that the PS textbook was more difficult to understand or had writing problems than the OT textbook (12 responses to five respectively), but more found the OT text more lengthy than the PS text (13 responses to seven respectively). One student responded the PS textbook contained, "some words too sophisticated for your average Joe" while at the same time noting that "the stucture of the writing made it easier to break down

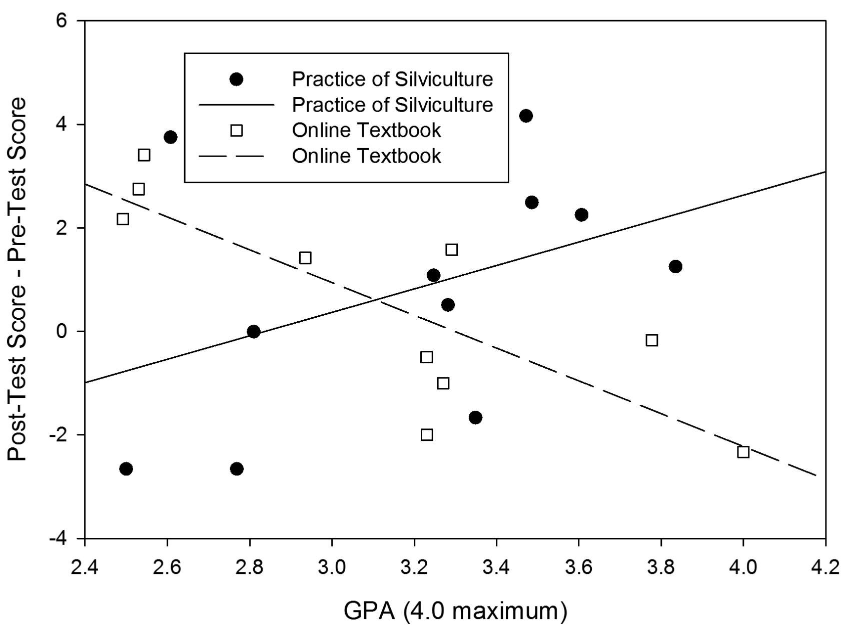

Figure 1. Simple linear regression of GPA and knowledge gain comparing an open educational resource online textbook (Stephen F. Austin State University Silviculture Online Textbook, OT) and a traditional print textbook (Smith et al. 1997 Practice of Silviculture, PS). Results are based on a survey of 21 students administered during the fall 2017 semester at Stephen F. Austin State University in FOR 347: Silviculture.

and understand the information." Thematic responses for students responding to the question concerning improvements to the texts noted that both could be shorter or more concise and needed to be more clear on certain points or overall, and that more visuals of a better quality were needed. One student in each group noted that their chapter could be "more interesting" or "less boring," respectively. These themes were consistent and approximately even for both textbooks.

Discussion and Conclusions

Both OT and PS led to broadly similar knowledge gains and similar preference levels in this study. Commonly the primary factor in an instructor selecting a course textbook is how well it meets the course learning objectives. Since both these texts performed similarly and were equally well received by the students, it would seem to suggest that other ancillary factors such as cost, print versus online media efficacy, and student learning preferences can be used by instructors to choose the best resource for their particular course. In our context, providing a resource designed for our region at no cost to students who on average graduate with a high debt load were key considerations. When selecting a text, students did report a preference for materials with many figures, preferrably of high quality and in color, with one student suggesting "make a video" as an improvement.

There are a number of important caveats and limitations to this study. Our sample size was relatively small, with students from only a single semester at a single university, and only compared a small amount of content equivalent to a single textbook chapter. For example, conclusions made on the impact of GPA on the efficacy of these resources are likewise limited in strength because of the small sample size (n = 11) and may not remain consistent over repeated sampling. OT was written expressly for undergraduate SFA students, whereas PS was written for a broad, international audience spanning a range of levels (undergraduate students, graduate students, postgraduates). This may have played a role in it performing similarly among this specific population. There is also a newer edition of PS that became available shortly after the conclusion of our study (Ashton and Kelty 2018). This 10th edition has been substantially revised and includes many more color illustrations and diagrams than the 9th edition. It is also available in electronic form as an e-book, unlike the 9th edition. It is possible this edition would have performed better in our study than the 9th.

While OER appears to be a viable learning tool in natural resource fields based on our study, it is not without drawbacks. Creating OER is labor- and time-consuming (Allen and Seaman 2016, COL 2017). It may not be a realistic approach for everyone based on teaching loads or other responsibilities. Creating OER may be disincentivized in fields with broadly distributed textbooks, as the authors may have the opportunity to earn more from book royalties than smaller professions that sell a smaller number of textbooks annually, such as silviculture. Further, because of the lack of available resources, OT has not been copyedited or peer-reviewed. It likely contains more errors than PS or other sources that have been produced through a publisher and have benefited from substantial amounts of input by experts.

However, there are also positive aspects to using OER. These materials may serve to benefit an outreach or extension mission in addition to the education of students enrolled in an institution. Anecdotally one of the authors has seen figures from OT appear in extension presentations, and several requests have been made to use these materials in other undergraduate silviculture courses. One student even noted the desire to have the textbook materials cater more to "our geographical area," a task that could be feasible using OER. Materials may be freely accessed by resource managers, landowners, policymakers, and others more readily than from a traditional textbook with a relatively higher cost. Given the rising costs of college education, many states and unversities are exploring options to lower the cost of college, including broad-scale implementation of OER across the curriculum as one promising avenue (Hilton et al. 2014, Williamson et al. 2016, Martin et al. 2017). Additionally, the impact on learning when students create OER is a significant benefit. Writing has been well documented as a means to improve various higher-order thinking skills in undergraduate students (e.g., Bean 2011). Anecdotally, the number of students requesting to write OT chapters has increased significantly since the publication of the first student chapter online, perhaps indicating a motivation to teach their peers or be recognized for their contribution to their peers' learning. Active learning led by peers is preferred by students and results in greater knowledge gains than more passive methods, such as instructor-given lectures (Minhas et al. 2012).

While there are many pros and cons to OER, our study does support that such materials are equally effective for learning as more traditional textbooks. Other factors, such as cost, format, local context, and faculty preference, can play a role in the selection of OER materials or traditional textbooks. However, as with any research, this project raised more questions than it answered. We hope in future studies to examine the effectiveness of different media (online versus print), how students acclimate to different types of resources, what types of students are served best by different resources and their availability, and how OER sources might be blended with more traditional textbooks to improve learning.

Supplementary Materials

Supplementary data are available at *Journal of Forestry* online.

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Appendix 1 – Knowledge Assessment Items

<u>Correct answers are underlined.</u>

1. An informal definition of a shelterwood is:
    a. A thinning method used primarily for shade intolerant species.
    b. A regeneration method used primarily for shade intolerant species.
    c. A thinning method used primarily for shade tolerant species.
    d. <u>A regeneration method used primarily for shade tolerant species.</u>
2. An informal definition of a seed-tree is:
    a. A thinning method used primarily for shade intolerant species.
    b. <u>A regeneration method used primarily for shade intolerant species.</u>
    c. A thinning method used primarily for shade tolerant species.
    d. A regeneration method used primarily for shade tolerant species.
3. Shelterwood and seed-tree methods both create (select all that apply):
    a. <u>Even-aged pure stands</u>
    b. <u>Even-aged mixed stands</u>
    c. Two-aged pure stands
    d. Two-aged mixed stands
    e. Uneven-aged pure stands
    f. Uneven-aged mixed stands
4. How many harvests occur in the most common application of a shelterwood?
    a. 1
    b. <u>2</u>
    c. 3

5. How many harvests occur in the most common application of a seed-tree?
    a. 1
    b. <u>2</u>
    c. 3
6. Which is NOT one of the primary reasons to conduct a preparatory cut?
    a. Improving vigor of seed-trees or overwood
    b. Removing undesirable seed sources
    c. Reducing litter layer thickness
    d. <u>Increasing value of future saw logs</u>
7. Which characteristics indicate that a species is **POORLY** suited to a seed-tree? Select all that apply.
    a. A light-seeded species
    b. <u>A heavy-seeded species</u>
    c. <u>A shallow-rooted species</u>
    d. A deep-rooted species
    e. <u>A species with shade tolerant seedlings</u>
    f. A species with shade intolerant seedlings
8. Which characteristics indicate that a species is **POORLY** suited to a shelterwood? Select all that apply.
    a. A light-seeded species
    b. A heavy-seeded species
    c. <u>A shallow-rooted species</u>
    d. A deep-rooted species

    e. A species with shade tolerant seedlings
    f. <u>A species with shade intolerant seedlings</u>

9. Which of the following is NOT a modification of seed-tree or shelterwood methods?
    a. Strip
    b. <u>Corridor</u>
    c. Uniform
    d. Group

10. How many 16 inch diameter loblolly pines need to be left per acre in a seed-tree cut?
    a. 2
    b. <u>4</u>
    c. 8
    d. 16
    e. 32
    f. 64