

Expanding the Reach of Crop Plants for Food Security: A Lesson Integrating Non-Majors Students Into the Discussion of Food Diversity and Human Nutrition

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Abstract

University general education (GE) courses host students with various academic backgrounds, interests, and perspectives. Engaging students in GE classes with agricultural issues can be challenging because of the diverse interests of students and the multifaceted nature of agricultural issues. Additionally, large-enrollment GE courses offered in auditorium style classrooms present physical constraints to collaborative and experiential learning. Here, we present an easy to implement lesson module in a GE course that solicits and integrates students' perspectives into in-class discussions and also leverages a discussion topic-centered writing component. This compact set of discussions is centered on the utilization of nutritious, but currently underutilized, grain crops from around the world that have historically functioned as a staple food in their respective cultures. The nutritional advantages of these grain crops as well as the agricultural, economic, and social constraints surrounding their global utilization are understandable to students in GE courses. In fact, the academic and geographic diversity of students in GE courses can use their personal experience with these crops and bring these considerations to light during in-class discussion. This lesson module serves both to familiarize students with food security related issues and to improve student agricultural literacy in a GE classroom setting. We envision that this lesson is suitable for courses within and beyond the plant science discipline. In addition, this lesson is amenable to implementation in classes that are either constrained in their physical ability to promote active learning, their contextual ability to discuss plant-related subject matter, or both.

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Supporting Materials: Supporting Files S1. Expanding the reach of crop plants for food security – Writing Assignment 1; S2. Expanding the reach of crop plants for food security – Midterm Questions Related to Discussion; S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides; S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides; S5. Expanding the reach of crop plants for food security – Class Discussion Points; and S6. Expanding the reach of crop plants for food security – Discussion Effectiveness Survey.

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Learning Goal(s)

Students will:

- know the nutrient profile of major staple grain crops that indicate their nutritional benefits and limitations.
- compare and contrast underutilized grain crops and major staple grains in terms of nutritional quality, traditional uses, and modern applications.
- recognize and explain the role that crop diversity plays in the global food system.

Learning Objective(s)

Students will be able to:

- evaluate the nutritional and agronomic advantages and limitations of different underutilized grain crops in the context of agricultural systems around the globe.
- distinguish the economic and social considerations that factor into the incorporation of currently underutilized grain crops in the global food system.
- relate issues surrounding crop cultivation and utilization to global challenges such as poverty, inequity, and food security.
- synthesize points from peer discussion and findings from scientific literature into written reports.

INTRODUCTION

Background

The global food system is based extensively on only a small number of consumable plants, and an even smaller fraction of all of the existing plant species. In fact, about half of the world calorie consumption comes from just three plants: wheat, maize, and rice (1). This lack of food diversity is seldom discussed in general education (GE) courses at the university level, and its entrance into the discussion is hindered by a general lack of attention given to plants—a phenomenon referred to as “plant blindness” (2,3). Plant blindness has brought about a lack of awareness to the interconnected factors that govern the continued health of global food systems (4). This lack of awareness is directly related to low levels of agricultural literacy, defined as “the understanding of social, environmental, and economic factors surrounding agriculture” (5). Running in parallel to heightened plant blindness in colleges and universities, agricultural literacy has also been steadily declining in populations of undergraduate students as the generations separating these students from agrarian lifestyles increases (6).

Some solutions have been proposed to address plant blindness in the university classroom setting. For example, a lab-based course has been proposed in which students care for a plant and document points in the plant’s life cycle (7). A writing assignment that leverages fond childhood experiences with plants has also been proposed to address plant blindness while also building students’ sense of place (8). The limitation of these lessons is that they do not tie into agricultural literacy directly. In addition, lab-based course interventions require a considerable amount of resources that are not generally offered to high-enrollment GE courses. Directly addressing agricultural issues in a classroom setting has been limited to issues that have received high publicity such as genetically modified organisms (GMOs) (9) or organic farming (10). Broadly speaking, studies focused on fostering agricultural literacy in a general sense are rare in postsecondary classrooms (11). Instead, educational efforts are focused on early education of future agriculture practitioners—an effort that trains professionals in an underserved area of national importance (12,13).

It is recognized that knowledge of plants allows members of the general student body to have more informed opinions about current events in public policy as they pertain to agriculture and sustainable human development, even if they are not the practitioners of agriculture (4). Expanding knowledge of plants in a global context is also useful for meeting the need for global learning in GE that has come into focus in recent decades (14). To improve agricultural literacy in the general undergraduate student population and raise the awareness of global citizenship, we designed and delivered a compact lesson module surrounding underutilized grains in our GE Plants and Society course. In this course, we discuss how plants provide food, nutrients, medicine, and fuels to humans as well as the intricate relationships between plants and the society. This course satisfies GE requirements for science and engineering, social sciences, and writing experience at our institution. Since this introductory course is open to all who have previously had high school biology, it draws students from all majors, class levels, and personal backgrounds. While most students enrolled in this course are freshmen or juniors transferred from community colleges with majors in different disciplines, there are also a

few upper division undergraduate students who are seeking GE credits to complete their bachelor degrees.

The compact lesson module includes a lecture and an in-class discussion that brings both major staple and currently underutilized grain crops to light within the context of food security. The module was centrally focused on several nutritious, but presently underutilized grain crops worldwide, specifically amaranth, broomcorn millet, chia, teff, and quinoa. Despite the nutritional advantages that these underutilized crops have relative to the three staple grains wheat, maize, and rice, the combined global acreage allocated to growing these underutilized grain crops fails to exceed that of wheat alone (15). This lack of global cultivation and utilization stems from numerous agricultural limitations (e.g., yield, growth habit) and social limitations (e.g., low consumer knowledge, negative perception) surrounding these underutilized grains. On the other hand, there are advantages of these crops, both agricultural and social, beyond their nutritional benefits that could make their utilization fruitful. The advantages and limitations of these crops regarding plant traits and human perspectives (examples outlined in Table 1) are a central theme of this lesson module.

The instructional activity is inclusive to many different academic, social, and demographic backgrounds. As the students are from various majors and class levels, and with diverse personal experiences, the utilization of amaranth, broomcorn millet, chia, teff, or quinoa can be considered from many perspectives (15). Students also benefit from studying a food crop they can utilize or have utilized, bringing a personal component into the in-class discussion that engages students by making the content relevant to them (16). Lastly, relevance of the topic to students is further expanded by the real-world context of these crops and the scientific literature surrounding them (17).

This course has barriers to active learning that are common in the university setting, such as high enrollment (>100 students) and a standard lecture hall layout (18). This high-enrollment lecture hall setting also inhibits the implementation of experiential learning with small groups and hands-on activities that has been shown to be effective at fostering agricultural literacy (19). Finally, our course is set in a 10-week quarter system, meaning that it is very fast-paced and potentially limited in its ability to cultivate classroom culture. Taking these challenges into consideration, we designed a compact and group participatory module that engages the class with these grain crops while being compatible with a high enrollment lecture hall and a tight course schedule. Leveraging and building upon student existing understanding has proven to be effective in active learning (20). Therefore, our lesson module also incorporates an out-of-class writing component that depends extensively on the in-class discussion while promoting student learning by having them consult scholarly literature.

In this easy to implement lesson module, students are provided with fundamental knowledge of major staple and underutilized grain crops in a lecture, which is supplemented with an out-of-class library session for gathering literature information on the grains. Students then engage in subsequent in-class discussion with their peers and take advantage of the prior experience of individuals across the entire classroom. The in-class discussion also gives students the flexibility to focus on the grain crop that they have the most prior experience with or that they are

personally interested in. This allows the students to make the lesson more personally relevant and beneficial (5). The lesson module weaves in a writing assignment in which students integrate what they have learned from the lecture, library session, in-class discussion, and scientific literature and further explore the marketing prospects of that grain crop in today's global market. Our lesson presented here is novel in that it promotes agricultural literacy in a course targeted at a broad, general audience of university students using a widely understandable and personally relevant context (11).

Intended Audience

The lesson was targeted at non-biology majors of all class levels enrolled in a Plants and Society GE course at a large research university. The required knowledge for our course offering was high-school level biology. During our implementation of the lesson, students across a diversity of majors (both STEM and non-STEM) and class levels (First Year – Senior) were present. The classroom used was a standard, auditorium-style lecture hall with a seating capacity of 120 students.

Required Learning Time

The core portion of the lesson module required two 50-minute class sessions. The first class session was used to familiarize students with underutilized cereal and pseudocereal grains, the latter of which produce seeds that resemble cereal grains, but do not belong to the same plant family as cereals. The first class session was also used to acclimate students to in-class discussion, as our lesson modules were employed early in the academic term. The second class session was used to allow students to build on the discussion in the context of their chosen underutilized grain crop.

One week before the lesson module, the writing assignment was posted on the course website and was also explained in class to prepare students for the module of lecture and discussion (Table 2). In addition, out-of-class library sessions were scheduled before the in-class discussion to assist students in their literature search on the underutilized grain of their choice. Overall, students had one week to prepare for the discussion and three weeks in total for the preparation of the writing assignment relating to this module: one week to submit a brief outline of the essay and two additional weeks to complete the paper on an underutilized grain crop.

Prerequisite Student Knowledge

Students are expected to have a familiarity with high-school level biology when registered for the class. Additional knowledge was not expected of students when they entered the class, but was delivered in the three lectures preceding the module. These included the scientific method, plants' roles as producers in the food chain, and the chemical properties of plants and plant products for human nutrition. These lectures were partially guided by student input and prior knowledge to acclimate students to having discourse with their classmates.

Prerequisite Teacher Knowledge

The instructor(s) should similarly have a familiarity with general, high-school biology. The instructor(s) should also be familiar with both staple and underutilized grains as well as the agricultural, social, and economic concerns surrounding them to promote and facilitate student discussion more effectively

(Table 1). Time management and the ability to cultivate free-form classroom discussion are crucial for the two-day module as well.

SCIENTIFIC TEACHING THEMES

Active Learning

In addition to group discussion, our lesson takes advantage of the teaching strategies below to encourage student engagement (21).

- Ask open ended questions
- Think-pair-share
- Hand raising (with inclusion of additional voices where possible)
- Integrate culturally diverse examples
- Monitor student participation

Assessment

Assessment of student learning took on two forms. Low-stakes formative assessments were conducted through observation of students' responses to open-ended questions and monitoring of think-pair-share activities. In addition, an outline of the writing assignment (a summative assessment in this module as discussed below) was due soon after the discussion periods and two weeks before the due date of the completed essay (see "Lesson Plan" in the next section). Evaluation and grading of the essay outline (ten percent of the writing assignment points) provided effective feedback on students' learning of the module and guided their preparation of the essay. The outlines and the final essays were graded based on students' articulation of topics from in-class discussion, integration of literature into their arguments, and on general writing composition. Students were made aware of this grading scheme before the discussion to encourage involvement in the discussion.

Summative assessments encompassed a writing assignment in the context of the discussion (Supporting Files S1. Expanding the reach of crop plants for food security – Writing Assignment 1) and questions on the midterm exam. The writing assignment served as a summative assessment for the lesson by giving us a means to gauge student understanding of the material. The writing assignment also functioned as a formative assessment within our course as a whole by enabling us to foster improvements in writing quality through feedback and tuning of later course material ahead of a separate, but similarly assessed writing assignment later in the term. Indeed, improvements to student writing quality were seen on the second writing assignment, which indicates a sustained impact of the lesson module on student writing efficacy.

In addition to the writing assignment, questions based on the content of the discussions were incorporated into the midterm exam of our course (Supporting Files S2. Expanding the reach of crop plants for food security – Midterm Questions Related to Discussion) and functioned as a summative assessment of the lesson module. The midterm was a standard multiple-choice exam, with questions from the in-class discussion amounting to ten percent of the content and weight of the exam. Students were notified of this midterm component and of the writing assignment before the lesson module to further encourage in-class participation (see Lesson Plan).

Inclusive Teaching

Our lesson used crops that have historical connections to

several different regions around the globe and that can be found on shelves of some grocery stores. As such, the discussion was amenable to the personal experiences of individuals from a multitude of backgrounds. In our discussion, student inputs from Central American, South American, and Asian cultural contexts were included to great effect. Alongside of that, inputs from other students that had consumed products made from teff, chia, and quinoa were woven into the discussion as well. While surveying discussions taking place around the classroom, we noticed parallel themes from other crops (e.g., kale, avocado, and maize) emerging in conversation as well.

In terms of instructor practices, involvement of a broader group of individuals was encouraged. During breakout group discussions, the instructor and the teaching assistant served both to stimulate discussion of quieter groups and to motivate involvement of more students in the breakout discussions. Also, though the whole-class discussion was guided mostly by about a dozen group reporters, both the instructor and the teaching assistant called upon students that were found to have novel inputs from the breakout discussion to give them an opportunity to showcase their ideas.

LESSON PLAN

The Writing Assignment

One week before the lesson module, the writing assignment was posted to the course website and announced in class. This writing assignment prompted students to recommend an underutilized grain crop of their choice to the purchasing team of a local food Co-Op (Supporting Files S1. Expanding the reach of crop plants for food security – Writing Assignment 1). Students were asked to consider the nutritional advantages of their chosen grain crop relative to the major staple grains, the social and agricultural issues surrounding the possible utilization of their grain crop, and marketing strategies to promote the crop. Preparation for this writing assignment was noted to students as a key objective of the in-class discussion periods.

An outline for the writing assignment was due three days after the in-class discussion (i.e., the conclusion of the lesson module) (Table 2; Supporting Files S1. Expanding the reach of crop plants for food security – Writing Assignment 1). Agricultural and social concerns of their chosen underutilized grain crop were necessary components of the outline and the final essay submission, motivating students to engage in the discussion with their classmates. The complete essay was due two weeks after the submission of the outline (Supporting Files S1. Expanding the reach of crop plants for food security – Writing Assignment 1). Students were expected to incorporate refereed scientific literature into their essay by integrating at least five peer-reviewed sources into their work. An extra credit, out-of-class library session was given twice before the in-class discussion in which a university librarian demonstrated the use of electronic resources for searching scientific literature for the writing assignment (Table 2).

The Discussion Module

Before the Discussion

Prior to the lesson module, students were introduced to major staple cereals that are rich in carbohydrates but generally low in vitamins and minerals, and to the lack of diversity present in the

global food system. The lesson module (including the discussion periods), the posting of the writing assignment, and the library sessions noted above were all announced in the preceding two classes as well (Table 2).

Module Day 1

Day one of the module began with an introductory mini-lecture on the major staple grains wheat, rice, and maize, which led into a segment about underutilized grains (Supporting Files S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides). In our class, this segment functioned as a re-introduction to the different types of grain crops, as cereals and pseudocereals were defined in a previous class period. The introduction to underutilized grains used images of several cereal or pseudocereal grains (Supporting Files S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides) and surveyed students for their familiarity with each of the grains shown. After the mini-lecture, students were encouraged to share with the class any dishes that they knew of that incorporated the underutilized grains displayed. Students reported out several dishes during this portion of the class—dishes that often highlighted the diverse experiences of the class members.

After several minutes of students reporting out, a second lecture phase of the class focused on a case study of quinoa, a nutritious, underutilized pseudocereal grain. Quinoa's journey to broader utilization has been tumultuous, with both social and agricultural considerations factoring into its wide adoption (22,23) (Supporting Files S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides). The economic and social concerns surrounding quinoa utilization have been the subject of many journalistic and academic investigations, making it a great place to start the discussion of leveraging traditional crops for human health and food security. The lecture portion on quinoa took up the middle of the class period and detailed the social and agricultural concerns surrounding quinoa, as well as the distinction between social and agricultural concerns more broadly. This lecture portion concluded with personal accounts from quinoa farmers and consumers that showed these concerns manifesting themselves in the South American communities that have consumed quinoa for generations (Table 2; Supporting Files S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides).

The final portion of the class period was allocated to open class discussion on the case of quinoa. The prompts below were used to cultivate discussion (Supporting Files S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides):

- What are your thoughts?
- Was the utilization of this underutilized crop successful?
- Do we have a debt to the locals that have aided the cultivation and spread of this crop?
- Why invest in underutilized grains? Can multivitamins substitute the nutrition from these otherwise useful grains?

The prompt “What are your thoughts?” was given to the class first, and responses were taken from individual students that raised hands, with no think-pair phase used for the first prompt. Each successive prompt was done one by one as a brief think-pair-share activity (21,24). Our class had many students

participating in the discussion with responses both agreeing and disagreeing with the presented question. The last question stirred the most discussion between students, with individuals reporting out eagerly and often without the need for instructor intervention. Day one ended by announcing again the coming discussion during the next class period and by noting the parallels between the in-class discussion and the theme of the writing assignment. Students were also reminded to select a grain to focus on for their writing assignment and the in-class discussion before the next class period. Lastly, the extra credit library sessions noted above were announced again at the end of this period. The library sessions covered similar materials and were scheduled at different times out-of-class to accommodate students' schedules.

Module Day 2

The second day of the module (two days after the preceding lecture) began with students picking up a colored card corresponding to their chosen underutilized grain and sitting in a quadrant of the classroom with other students that had selected on same grain (Supporting Files S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides). A white “undecided” card was available to students that were unsure of their grain choice. However, no students picked this card in our class. Though there was a strong preference toward chia and less of a preference for broomcorn millet in our class (Figure 1), each group had enough students to enable discussion.

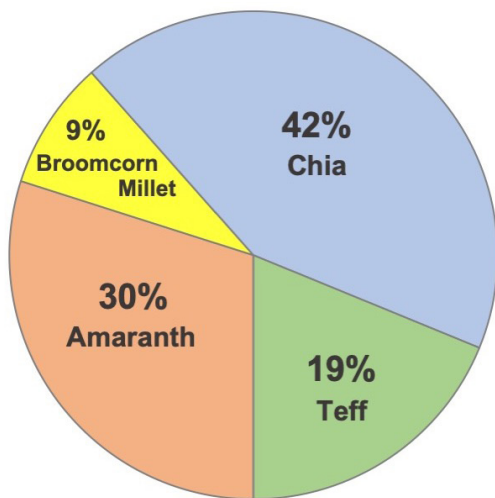


Figure 1. Grain choices by students for the in-class discussion.

As students were getting settled, the instructor gave a five-minute recap of the social and agricultural concerns surrounding quinoa cultivation (Table 2). The card colors were noted on the bottom of all slides so that late arrivals could get oriented (Supporting Files S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides). Transparent bags with each of the five underutilized grains introduced on Day 1 of the module were passed around the class during the introduction as well. Note that quinoa was discussed on Day 1 and not the focus of discussions on Day 2. After the brief recap, the following discussion questions were used one by one:

- What are some agricultural concerns surrounding other underutilized grains?
- What are some social and economic concerns surrounding other underutilized grains?

- Are there any recurring themes?
- Is utilizing underutilized grains worth it?

For each question, students in each grain group discussed among themselves for two to five minutes, with the instructor working to engage less active groups of students. For the first prompt, members of each grain group were told to report out, starting with the group with the largest number of members (chia in our case). For successive prompts, a mixture of hand-raising and cold-calling was used to take advantage of self-nominated group reporters while also giving quieter students a chance to include their perspectives.

The third and fourth discussion prompts served multiple purposes. Firstly, conversations around these prompts brought together and re-packaged the points from prior discussions, allowing students to synthesize the ideas from prior discussion among themselves with only minimal instructor input. This portion of the discussion also served to address key components of the writing assignment, namely the section in which students suggest a marketing strategy for their respective grains at the local food Co-Op. In our classroom, the open discussion surrounding the fourth discussion prompt was robust and spontaneous. Perspectives from students came from many different angles and required only minimal synthesis and repackaging by the instructor.

In the case of extra time, a fifth discussion prompt was prepared for students: “Are there any other interesting points about your underutilized grains that you would like to share?” (Supporting Files S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides). Discussion of the worth of utilizing underutilized grains used up the remaining class time, so this discussion question was not used in our class. We believe that this last prompt could be used in longer classes either to start the discussion or to make fruitful use of remaining time after the fourth discussion question.

Points raised by students during the discussion were summarized and posted to the course web page (Supporting Files S5. Expanding the reach of crop plants for food security – Class Discussion Points). Students were informed that content from the discussion would be present on the first midterm exam and were encouraged to look back on those discussion notes. We acknowledge that focal points of discussion can vary widely based on the backgrounds of the students, but we believe that many of the points raised by our students are likely to appear in other classrooms as well.

TEACHING DISCUSSION

We were interested in getting student feedback on the lesson. Student input was elicited for the lesson using a five-point Likert scale and an open response question where students could supply input for the improvement of the lesson (Supporting Files S6. Expanding the reach of crop plants for food security – Discussion Effectiveness Survey). This survey was anonymous and filled out by approximately three quarters of the students (87 students out of 117). The Likert scale prompts on this survey were the following:

1. The discussion sections improved my understanding of underutilized grain crops, including their advantages

and limitations.

2. The discussion sections improved my ability to write critically about these underutilized crops in the first writing assignment.
3. Inputs from students were incorporated well during the discussion sections.
4. I was personally interested in the content of the discussion sections.
5. The discussions were executed effectively.

Likert-Scale Responses

Responses to the Likert scale portion of the survey were overall positive. For the first three prompts and the fifth prompt, over 60% of students agreed or strongly agreed with the statement and only less than 12% disagreed, with disagreement being close to zero for some prompts. In addition, the positive impact of the discussion sessions was also reflected in the writing assignment. Both STEM and non-STEM major students were able to proficiently integrate a variety of social, agricultural, and economic factors related to their chosen grain crop into their essays. The average score on the writing assignment was 90.8% out of 100%.

In response to the prompt “I was personally interested in the content of the discussion sections,” approximately 13% of the students disagreed with the statement and another 40% showed a neutral response. As a GE course, our class was comprised of students from a wide range of STEM and non-STEM majors, and a great majority of the students did not have an agricultural component to their degree program. Therefore, it is conceivable that some students may not have personal interest in the subject matter when entering this class, which is consistent with the observation of plant blindness in the general student body. On the other hand, the response to this question highlights the need for promoting agricultural literacy in GE courses, the inspiration that motivated us to design and deliver this lesson module in the first place. These efforts appear to have made a positive impact on students’ learning. When anonymous teaching evaluations were conducted at the end of the quarter, students indicated that “the overall educational value of the course” was very good to excellent with the options of poor (1), fair (2), satisfactory (3), very good (4), and excellent (5).

Student Suggestions for Improvement

In the open-ended suggestions portion of the survey, students noted their perceptions toward the discussion session and often supplied suggestions for future discussions on the same subject. Aligning with the results of the Likert survey, most of the responses were very positive, with comments noting the diverse perspectives brought by classmates and the benefit of splitting the class into grain groups. The critical comments highlighted an aspect of the lesson that could be refined: students are not under a strict obligation to select or research their chosen grains before the in-class discussion. In our class, the writing assignment that requires students to select a grain crop was announced in advance. However, the writing assignment was designed to be due after the in-class discussion, allowing students to integrate information and resources from discussion into their assignment submissions. As shown in the responses to the Likert-scale survey, over 60% students agreed with the statement that “The discussion sections improved my ability to write critically about these underutilized crops in the first writing assignment”. Nonetheless, students are not without

previous experiences for the in-class discussion, and this likely accounts for the fact that the white undecided card was not picked by any students during the second day of the module. In fact, many personal experiences with these grain crops emerged in discussion—both from cultural heritage and from routine consumption in everyday dishes.

When moving this discussion module into another classroom, particularly in a semester system with a less compact course schedule, a slight modification to the class assignment such as the addition of a small, related assignment (e.g., a blog post or a reading assignment) before the discussion would give students more exposure to their chosen grain crop before the discussion. Having students work on a small assignment in advance may curb the lopsidedness toward chia as well. We noticed that when asked for a show of hands during in-class discussion for the question “How many of you had heard of your grain crop before?”, raised hands were concentrated in the chia group. It is possible that relatively unprepared students may have defaulted to chia in the discussion because it was the grain crop those students had prior exposure to.

Adapting the Lesson for Other Classrooms

The lesson module presented here is easily adapted to other classrooms and institutions. In contrast to other larger-scale course reformations, this module has the advantage of being cost-effective and compact, enabling its incorporation into inflexible or underfunded courses. The compactness of this module and its writing assignment allows it to serve as a formative assessment for writing efficacy within courses that have improved writing ability as a learning goal, such as our GE course. This enables instructors to tailor subsequent course materials to meet specific learning and writing needs in their classroom. In addition, the global perspective of this easily installed lesson makes it a valuable addition to general courses with little or no plant biology component, which could help curb the decline of plant biology and agricultural science content in college classrooms (25).

Given that the decline in agricultural literacy among incoming undergraduate students has occurred in parallel to the decline of plant biology content in classrooms (6,11,26), fostering agricultural literacy in the classroom is another key benefit of the lesson module. It has been shown that prior agriculture coursework experiences were associated with greater understanding of agriculture related issues in incoming undergraduates (6). As such, we believe that this lesson module and its accompanying writing assignment can help foster agricultural literacy by having students in our course unpack agricultural related social, environmental, and economic issues in a case-study format. Furthermore, the integrated writing component of this lesson module enables it to be used in courses that fulfill institutional writing requirements aimed at resolving known writing gaps in incoming undergraduate students (27).

The lesson could be adapted in a number of ways to fit different classroom contexts. The length of time allocated to each discussion question could be extended or more discussion questions could be added (such as the unused fifth question noted on day 2) to accommodate longer class periods. The content of the lesson is also flexible. While we have opted to focus on these five grain crops, the lesson is not constrained to these specific grains. As students benefit from learning content that is relevant

to them (16) and because the in-class discussion calls heavily on personal experiences, the underutilized crops at the center of this lesson can be changed to fit the social and agricultural context of the college or university. This allows the instructor to tailor the lesson to fit the personal experiences of the students while still anchoring the lesson in the interconnected concerns that surround plant cultivation by human society (4, 11, 29). Such personal experiences were noted in our classroom discussion for each of our grains, and these experiences added unique perspective to our Plants and Society course offering.

SUPPORTING MATERIALS

- S1. Expanding the reach of crop plants for food security – Writing Assignment 1
- S2. Expanding the reach of crop plants for food security – Midterm Questions Related to Discussion
- S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides
- S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides
- S5. Expanding the reach of crop plants for food security – Class Discussion Points
- S6. Expanding the reach of crop plants for food security – Discussion Effectiveness Survey

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Table 1. Survey of advantages and limitations for each of the underutilized grain crops examined in this lesson.

Grain Crop	Advantages	Limitations
<i>Amaranth</i>	<ul style="list-style-type: none"> • C₄ photosynthesis • Can be popped, broadening use 	<ul style="list-style-type: none"> • Darker grain color is not favored by some consumers • Growth sensitive to soil structure • Inconsistent maturity; requires frost
<i>Broomcorn Millet</i>	<ul style="list-style-type: none"> • C₄ photosynthesis • Drought tolerant • Fast growth cycle 	<ul style="list-style-type: none"> • Inconsistent maturity time • Perceived widely as pet food
<i>Chia</i>	<ul style="list-style-type: none"> • Use in beverages becoming widespread • Effective source of ω-3 fatty acids • Useful as thickener, egg substitute 	<ul style="list-style-type: none"> • Photoperiodism limits range of cultivation • Gelatinous mucilage and low starch content limits its use as a starchy grain for baking
<i>Teff</i>	<ul style="list-style-type: none"> • C₄ photosynthesis • Persistent traditional knowledge exists regarding use 	<ul style="list-style-type: none"> • Growth sensitive to soil structure • Darker grain color is not favored by some consumers • High lodging rate
<i>Quinoa</i>	<ul style="list-style-type: none"> • Has garnered expansive research into its growth, marketing, and cultivation • Already incorporated into recipes 	<ul style="list-style-type: none"> • Removal of seed coat (containing saponins) required • Cultivation is highly centralized in the high-altitude Altiplano region
<i>Common to all five underutilized grains</i>	<ul style="list-style-type: none"> • Amenable to machine harvesting • Generally tolerant to biotic and abiotic stresses • Highly nutritious relative to the major staple grains in terms of vitamin and mineral quantities, and balanced amino acid content 	<ul style="list-style-type: none"> • Unfamiliar to growers and consumers outside of the traditional region of cultivation • Fluctuations in markets can negatively impact traditional growers • Low yield

Table 2. Lesson timetable for the discussion module and for course components leading up to and contributing to the lesson module.

Activity	Description	Estimated Time	Notes
In Classes Before the Lesson Module			
Introduction to the Scientific Method	An introduction to the scientific method was given to students on the first day of the class after the course overview. This intended to prepare students for reading scientific literature.	25 min	
Introduction to the Writing Assignment	The goals and context of the writing assignment were introduced to students in the class period before the lesson module. Expectations for originality and writing quality were also noted. Students were encouraged in this section to read into the grain crops in the writing assignment. Two extra-credit library sessions were announced in this time block. These library sessions occurred after day one of the module and assisted students with their literature search for the writing assignment (see below).	15 min	The writing assignment was posted to the course website and announced one week before the lesson module.
Module Day 1			
Introduction to staple and underutilized grains	Introduces students to the concept of grain crops, as well as the difference between cereals and pseudocereals.	5 min	The discussion questions and content of this lesson are in Supporting File S3. Expanding the reach of crop plants for food security – Module Day 1 Lecture Slides.
Elicitation of student input	Question was posed to the class: <i>Where would you find these underutilized grains locally?</i> This was followed by the question: <i>What do we make with these grains?</i>	5 min	
Lecture component: The pros and cons of quinoa utilization	This component discusses the pros and cons of quinoa utilization. This section introduces students to the difference between social and agricultural considerations as well.	25 min	
Class discussion: How well did we utilize quinoa?	Questions posed: <ul style="list-style-type: none"> • <i>What are your thoughts?</i> • <i>Was the utilization of this underutilized crop successful?</i> • <i>Do we have a debt to the locals that have aided the cultivation and spread of this crop?</i> • <i>Why invest in underutilized grains? Can multivitamins substitute the nutrition from these otherwise useful grains?</i> 	15 min	
Library Sessions			
Library session	A university librarian gave a demonstration of the university's library resources that directly pertained to our writing assignment. Students were also shown how to distinguish refereed and non-refereed literature. Students attending these library sessions were able to follow along on their own computers. About half of each library session was devoted to questions from students about scholarly literature and the navigation of library resources.	60 min	These sessions were scheduled outside of class between Module Day 1 and Module Day 2. Two similar sessions were offered at different times to accommodate students' schedule. Attending students were given extra credit.

Activity	Description	Estimated Time	Notes
Module Day 2 (two days after Module Day 1)			
Preparation for class	Colored cards should be labelled with the grains "Amaranth", "Broomcorn Millet", "Chia", and "Teff" clearly. Students will grab the cards and sit with classmates having the same card in a labelled quadrant of the classroom. Colored pages with the names of the grain written on them should also be made to label the quadrants of the classroom during class time.	30 min	Cards in our case were made with colored construction paper.
Immediately before class	Students grab colored cards corresponding to their grain crop of choice and sort themselves into quadrants of the classroom labelled both by the first slide of the presentation and by colored pages taped to the wall at the quadrant of the classroom. Undecided students grabbed white cards and could sit with any grain group of their choice.		Early arriving students were sitting before the slide was displayed and needed to relocate around the classroom. The discussion questions and content of this lesson are described in Supporting Files S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides.
Recap: The case of quinoa	A brief recap of the previous discussion on quinoa in Module Day 1 was provided to give students a refresher on the case of quinoa and the agricultural and social considerations surrounding its cultivation. This recap session allows late arriving students to trickle in and grab the cards corresponding to their grain crop of choice.		A panel was present on the bottom of all slides showing the organization of the grain groups (Supporting Files S4. Expanding the reach of crop plants for food security – Module Day 2 Lecture Slides).
Discussion: Cases beyond quinoa	The following questions were leveraged for in-class discussion: <ul style="list-style-type: none"> • What are some agricultural concerns surrounding other underutilized grains? • What are some social and economic concerns surrounding other underutilized grains? • Are there any recurring themes? • Is utilizing underutilized grains worth it? • Are there any other interesting points about your underutilized grains that you would like to share? Students discussed with their neighbors in the same grain group first, then were prompted to report out to the class. The instructor and the teaching assistant moved around class to stimulate discussion in quiet groups.	45 min 5-15 minutes per prompt	For the first two questions, grain groups were called on individually, starting with chia. The last prompt allows for flexibility in case the discussion runs short for the other prompts. The fifth prompt also allows for adaptation to longer classes.

Note: The outline of the writing assignment was due 3 days after Module Day 2. The complement essay was due 16 days after that to allow grading of the outlines and providing feedback to the students.