Emphasis on Quality in iNaturalist Plant Collections Enhances Learning and Research Utility

By Mason C. McNair, Chelsea M. Sexton, and Mark Zenoble

Following the switch to remote online teaching in the wake of the COVID-19 pandemic, the plant taxonomy course at the University of Georgia (UGA) switched to iNaturalist for the specimen collection portion of the course requirements. Building off extant rubrics, the instructors designed project guidelines for a fully online plant collection experience to alleviate plant awareness disparity. Researchers collected stratified samples from the UGA iNaturalist project along with four other institutions’ projects to determine if rubrics and project guidelines could improve the quality of observations to make them useful in plant science research. The specific rubric was shown to improve quality of iNaturalist observations. Researchers found that iNaturalist increased engagement as a student-centered tool but did not enhance students’ manual keying skills, as the app uses automatic identification. Instructors recommend continuing to use iNaturalist to supplement physical collection and keying along with a detailed rubric and guidelines for collection.

Modern plant taxonomy utilizes both phenotypic and genotypic data to group populations of plants into understandable groupings that we call species. Teaching students to appreciate this classification process is challenging and was more difficult during the COVID-19 pandemic. The Plant Taxonomy course at the University of Georgia (UGA) aims to enable students to explain the importance of plant taxonomy in the context of conservation, systematics, and species concepts. Within this goal, the students learn to correctly apply plant morphological terminology and identify plants by sight and using a dichotomous key. Through the learning process, we hope to alleviate plant awareness disparity (PAD), formerly known as plant blindness, by opening the students’ eyes to the plants surrounding them (Balas & Momsen, 2014; Jose et al., 2019; Krosnick et al., 2018; Parsley, 2020).

Plant taxonomy is often assessed through a plant collection project that authentically familiarizes students with botanical terminology, dichotomous keys, pressed plants, and, more recently, iNaturalist (Krimmel et al., 2021; Liston & Struwe, 2018). Plant identification has traditionally been a tactile experience in which students manipulate specimens, experiencing the textures and orientations of leaves, stems, flowers, and fruit. There are 620 plant families made up of 16,167 genera, and approximately 391,000 species globally, with new species being discovered on a continuous basis. Although it is impossible to memorize them all, students can make use of the skills and knowledge they acquire through plant taxonomy courses and published dichotomous keys to identify nearly every species on the planet. Dichotomous keys are an incredible tool that taxonomists of all fields of biology and beyond can use to help narrow the specific taxonomic identity of an organism of interest. By providing relatively simplified pairs of choices that either succeed or fail to fit the description of the organism of interest, someone unfamiliar with a specific taxon may be led to the exact species of plant using only simple dissection tools.

iNaturalist is designed to help anyone connect with nature by providing a one-stop shop for organismal identification, social media, locality data, and wildlife photography. The site was designed with ease of use in mind, as well as to aid scientists with data collection. With more than 300,000 active users, iNaturalist is one of the most successful citizen science projects and has been used in more than 120 peer-reviewed scientific papers (see https://www.inaturalist.org/stats). Anyone can upload photos, videos, or audio to iNaturalist through the app or website, and using automated image recognition, they can receive a tentative identification of an organism. Although helpful, these suggested identifications can lack specificity and require experts or the use of a dichotomous key to properly identify to genus or species level (Heberling & Isaac, 2018; Jones, 2020). However, iNaturalist’s
ability to identify organisms using its automated recognition software will only improve as more observations are made. Teaching identification using dichotomous keys and hands-on experiences will remain a core part of all plant taxonomy courses until the software is perfected. iNaturalist provides the perfect platform for university courses to explore and expand citizen science efforts.

iNaturalist does not use traditional tactile methods for identification. However, the ability to work with a global online community connects scientists, amateurs, and students in a way that manual keying cannot. Using a dichotomous key in an in-person lab setting can be collaborative as students work together on the same plant to use the provided key, but iNaturalist allows for a more diverse collegiality among different people, institutions, and regions. As the course at UGA included both plant biology major and nonmajor students, iNaturalist provided a way to encourage citizen science without overwhelming students with the advanced botanical vocabulary often required to use dichotomous keys in traditional classrooms.

Building on past projects, we aimed to implement an improved plant collection project that achieved three main objectives for our students:

- Students should be able to correctly apply plant morphological terminology.
- Students should be able to identify plants to the species level using dichotomous keys.
- Students should be able to create high-quality plant observations on the iNaturalist platform that are useable for future scientific research.

### Methods

iNaturalist has more than 36.6 million observations recorded for plants alone. Although many observations are unaffiliated with specific groups, there is a feature in iNaturalist that enables university professors to create projects to which their students can contribute. Data from eight different university plant collection projects, completed between March 2020 and May 2021, were downloaded from their project pages on iNaturalist (Table 1). The eight projects included a total of 6,911 observations. The raw data were filtered to exclude non–research grade observations (e.g., lacking two or more confirmed identifications to species level), non-plant observations (e.g., animals, fungi), and observations lacking locality data.

In many of the projects, students were motivated to submit more than

<table>
<thead>
<tr>
<th>Institution</th>
<th># of observations (raw)</th>
<th># of observations (filtered)</th>
<th>Included in analysis</th>
<th>Project link</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Missouri (MU)</td>
<td>147</td>
<td>64</td>
<td>No</td>
<td><a href="https://www.inaturalist.org/projects/mu-plant-systematics-inaturalist-project-2020">https://www.inaturalist.org/projects/mu-plant-systematics-inaturalist-project-2020</a></td>
</tr>
<tr>
<td>Lucian Blaga University of Sibiu (LBU)</td>
<td>390</td>
<td>59</td>
<td>No</td>
<td><a href="https://www.inaturalist.org/projects/bioblitz-sibiu-2021-ecosystems-ecosistemeforamen">https://www.inaturalist.org/projects/bioblitz-sibiu-2021-ecosystems-ecosistemeforamen</a></td>
</tr>
<tr>
<td>Connecting Students to Citizen Science and Curated Collections (CSCSCC)</td>
<td>841</td>
<td>441</td>
<td>Yes</td>
<td><a href="https://www.inaturalist.org/projects/connecting-students-to-citizen-science-and-curated-collections">https://www.inaturalist.org/projects/connecting-students-to-citizen-science-and-curated-collections</a></td>
</tr>
<tr>
<td>University of Georgia (UGA)</td>
<td>1094</td>
<td>640</td>
<td>Yes</td>
<td><a href="https://www.inaturalist.org/projects/pbio-4650-6650-2021-collections">https://www.inaturalist.org/projects/pbio-4650-6650-2021-collections</a></td>
</tr>
<tr>
<td>Rutgers University (RU)</td>
<td>1089</td>
<td>913</td>
<td>Yes</td>
<td><a href="https://www.inaturalist.org/projects/rutgers-pldivevol-fall-2020">https://www.inaturalist.org/projects/rutgers-pldivevol-fall-2020</a></td>
</tr>
<tr>
<td>University of California at Berkeley (UCB)</td>
<td>2011</td>
<td>551</td>
<td>Yes</td>
<td><a href="https://www.inaturalist.org/projects/ib-168ls-2021">https://www.inaturalist.org/projects/ib-168ls-2021</a></td>
</tr>
<tr>
<td>University of Hawai‘i at Manoa (UH)</td>
<td>249</td>
<td>62</td>
<td>No</td>
<td><a href="https://www.inaturalist.org/projects/bot461-uh-manoa">https://www.inaturalist.org/projects/bot461-uh-manoa</a></td>
</tr>
<tr>
<td>Oregon State University (OSU)</td>
<td>1090</td>
<td>980</td>
<td>Yes</td>
<td><a href="https://www.inaturalist.org/projects/bot321-plant-systematics-2021">https://www.inaturalist.org/projects/bot321-plant-systematics-2021</a></td>
</tr>
</tbody>
</table>

**Note.** Institutions not included in the iNaturalist project analysis were delimited due to a dissimilarity of the rubric used for student instruction and grading as well as their smaller numbers of student observations.
the required number of observations or to resubmit observations originally deemed below par. Although this encouragement may reduce the percentage of useful observations in a project, it is pedagogically sound to allow students the chance to revise and explore in student-centered projects. Plant taxonomy university projects were identified at Rutgers University (RU), University of California at Berkeley (UCB), Oregon State University (OSU), and the Connecting Students to Citizen Science and Curated Collections (CSCSCC) Project, which includes classes from Arkansas State University, University of Michigan, Central Michigan University, and Middle Tennessee State University. These university projects were chosen based on their similar rubrics and larger numbers of observations. A stratified random sample of 160 observations was taken from each selected university’s project (excluding our own). The UGA project had a total of 640 observations after filtering, all of which were included in the analyses, for a grand total of 1,280 observations across all universities. Observations were blinded by removing all identifying information except the iNaturalist observation identification number, web address for the observation, and species identification before being scored using our custom rubric (Table 2).

In designing the rubric, we searched the the Botany Depot website for extant rubrics. Aaron Liston published a rubric; soon after, professors from the CSCSCC published a similar rubric on their own website. All projects included in the analyses were based on either the Liston or CSCSCC rubrics, which share similar grading criteria and learning objectives (Krimmel et al., 2021; Liston & Struwe, 2018). Students at UGA were shown how to make observations in an iNaturalist project and given a rubric at the beginning of the semester (Appendix A). The rubrics made available from all colleges’ projects were based on the same premise of wanting to create research-grade photographic collections. In addition to the requirements of the original rubrics, the UGA rubric required student observations to include a minimum of four photographs of the plant, with at least one image containing a coin or ruler for scale. Images were required to show leaf shape, leaf arrangement, stem, reproductive structures (fruit or flowers), and overall habit of the plant (how it grows). Every observation was required to contain all the necessary information to make a proper herbarium label in the observation notes section. Undergraduate students were required to submit 20 observations, and graduate and honors students were required to submit 30 observations. Lastly, each student was required to key out (identify using a dichotomous key) two of their classmates’ observations and three of their own and post the steps as a comment on iNaturalist.

Scoring was completed using a robust rubric designed to assess the ability of an observation to be identified using a dichotomous key and utilized by researchers (Table 2). The rubric was designed to reward observations that included the level of detail often required for identifying a plant to the species level using a dichotomous key. Orientation, count, and tiny details such as presence or size of glands, hairs, or vein patterns are not infrequently the deciding factor in a dichotomous key. Although many plants, such as lilies and roses, may have large, easily observable flowers, there are far more flowering plants we pass by daily that have much smaller flowers (e.g., grasses). The more of these fine details that were captured in the observation photos, the higher the score and the more utility that observation has for future research. Observations that were pressed, cultivated, completely plucked from where they were growing with no indication of where they came from,

<table>
<thead>
<tr>
<th>Point value</th>
<th>Trait</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Photo(s) show leaf</td>
</tr>
<tr>
<td>1</td>
<td>Photo(s) show habitat (3 points of reference to provide context, e.g., surrounding vegetation, light levels, anthropogenic structures)</td>
</tr>
<tr>
<td>1</td>
<td>Photo(s) show growth habit (tree, shrub, vine, herb, etc.)</td>
</tr>
<tr>
<td>1</td>
<td>Photo(s) show leaf arrangement (opposite, alternate, whorled)</td>
</tr>
<tr>
<td>1</td>
<td>Photo(s) show mature reproductive structures (flower, fruit, cone, spores)</td>
</tr>
<tr>
<td>1</td>
<td>If angiosperm: Photo(s) show enough characters to create at least 3/5 parts of a floral formula (flower shape[bilateral/radial], # sepals, # petals, # anthers, ovary superior/inferior); or fruit shows cross section</td>
</tr>
<tr>
<td>1</td>
<td>If gymnosperm: Photo(s) show male and female reproductive structures</td>
</tr>
<tr>
<td>1</td>
<td>If fern: Indusium clearly visible</td>
</tr>
<tr>
<td>1</td>
<td>If lycophod: Sporing structure clearly visible</td>
</tr>
<tr>
<td>1</td>
<td>Photo(s) contain ruler or coin for scale (hands and random objects do not count)</td>
</tr>
</tbody>
</table>
Emphasis on Quality in iNaturalist Plant Collections Enhances Learning and Research Utility

Results

Each of the five universities or consortia sampled included observations that represented the full range of the rubric, from 0 to 7 points, and all average scores were above 3.5 points. Despite UGA having more observations than the other groups included in analysis, the standard deviation of UGA’s observations (1.51) was in the middle of the other four universities (OSU = 1.31, UCB = 1.47, CSCSCC = 1.75, RU = 1.80). OSU had the highest mean score (5.26), followed by UGA (5.07). The other three projects’ scores were significantly lower \((p < 0.05)\), with UCB scoring an average of 4.27, CSCSCC scoring an average of 3.96, and RU scoring an average of 3.76 (see Figure 1). The median and mode of UGA and OSU were 5 points and 6 points, respectively. CSCSCC and UCB showed median and mode of 4 points and 5 points, respectively, and RU showed 4 points for both measures.

During scoring, most of the points missed resulted from a lack of photographic detail of reproductive structures and overall habitat, as well as a failure to include a standardizable scale in at least one photograph. The ANOVA revealed that the observations in our project (UGA) had significantly higher scores than CSCSCC, UCB, RU, and all institutions included combined \((p < 0.001)\). However, our observations were not significantly better than the ones from OSU \((p = 0.64;\) Figure 1). OSU also had significantly higher scores than all other institutions except UGA (see Figure 1).

Discussion

The global pandemic forced lab- and lecture-based classes to move online in spring 2020. Plant taxonomy has rarely, if ever, been offered in an online format. At UGA, this transition to online learning required extensive updating and modification over a 2-week period in March 2020 and throughout the spring 2021 semester (plant taxonomy is not offered in fall semesters). One of the greatest losses of moving to remote teaching was the inability to discuss with students the discoveries they made for plants that they have in hand. Using iNaturalist, students can go for a walk around their neighborhood, take pictures of any plant they happen across, and receive a best guess on the identification immediately. This jump-starts learning about the plant they came across, and they may choose to include these plants in their collection project. After add-

![FIGURE 1](Comparison of observation scores among institutions.)

Note. (A) Total number of observations for each score category; colors indicate institution. (B) The average change in mean response (mean score) when comparing institutions. (C) Percentage of observations for each score; color indicates institution.
ing a plant observation to the iNaturalist app, students could easily add it to the class project for instructors to review, comment on, confirm, or reject.

Through the semesters, we found several negative effects on our students’ learning as a result of remote instruction and reliance on iNaturalist over physical keying. Dichotomous keys require practice and experience for proper use. If students are introduced to iNaturalist in a classroom setting before becoming comfortable with identifying specimens using dichotomous keys, the automatic identification capabilities can be used to circumvent exercising keying skills. Students may no longer feel the need to learn the process of keying out specimens to get a potential identification if there is an app giving them a putative answer. The problem remains that app-based identification is far from perfect. iNaturalist was only able to identify plants to the correct species 35% of the time, and it provided entirely incorrect, misleading identification 16% of the time (Jones, 2020). Even if the identification is only to family level, if it is correct, then students need not utilize the key to family in the flora being used for identification (i.e., if the app’s identification is partially correct, it is detrimental to student learning).

However, different aspects of student learning were improved through use of iNaturalist. Making plant taxonomy a student-centered learning experience rather than a content-centered course should be a priority. Having clear, learner-oriented objectives, instructions, and rubrics available to students at all times gives the students the power to succeed while being able to students at all times gives the project feedback to use in future semesters (Appendix B). Even with only 20 observations required for undergraduates and 30 observations required for graduate and honors students, the instructors were approached multiple times with concerns of the collection project being overwhelming. Providing students with extra opportunities to make observations for the project during optional field trips scheduled outside of normal class time seemed to alleviate most of these issues.

One of the primary goals of plant taxonomy courses is to give students the skills to take nearly any plant they encounter through a dichotomous key and identify it to the species level. Distinguishing a specimen using a key often requires dissecting reproductive structures (flowers and fruits) at a fine level with great attention to detail. iNaturalist provides a less-invasive option for recording the presence of rare and endangered species. Unlike pressing plants, iNaturalist observations are nondestructive and can provide a plethora of habitat, ecological, environmental, and climate information. However, iNaturalist is not a replacement for physical collections. Herbaria and the physical plant collections they contain are invaluable as a source of morphometric and genetic data (Bieker & Martin, 2018; Fritsch et al., 2018; Miller-Rushing et al., 2006; Weaver et al., 2020). However, photographs of living specimens do provide additional insights, especially when exact locality, date, and time information is included and photos showcase three-dimensional aspects not captured in the pressing process. Some herbaria have even begun integrating photography into their collections to facilitate this new source of information (Gómez-Bellver et al., 2019; Heberling et al., 2019; Heberling & Isaac, 2018).

Conclusion

The changes made to the UGA plant collection project and rubric significantly improved the quality of iNaturalist observations with regard to students’ ability to run through a dichotomous key to species-level identification compared with all other universities combined. The rubric required student observations to include more and higher-quality details for each observation. These observations are more likely to be suitable for use in research studies (Barve et al., 2020; Echeverria et al., 2021; Gazdic & Groom, 2019; Schiller et al., 2021; Van Horn et al. 2018). It is our hope that plant taxonomy courses will make use of the rubric moving forward and will continue improving on it in a student-centered manner.

References


Emphasis on Quality in iNaturalist Plant Collections Enhances Learning and Research Utility


**Mason C. McNair** (mcnair5@clemson.edu) is a postdoctoral fellow in the Department of Plant and Environmental Science at the Clemson University Pee Dee Research and Education Center in Florence, South Carolina. **Chelsea M. Sexton** is a PhD candidate in the Department of Education at the University of Georgia in Athens, Georgia. **Mark Zenoble** is an environmental specialist in the Division of Plant Industry for the Florida Department of Agriculture and Consumer Services in Davie, Florida.