# Teaching Plant Morphology in an Active Learning Setting with Digital Microscopes

## Introduction

Plant identification courses are integral to forestry, horticulture, landscaping design, natural resources and weed science curricula. Instruction typically entails teaching plant morphological features in field, nursery, greenhouse, conservatory, or landscape settings. Current data suggest landscape horticulture employers rank plant identification skills highly for career success (Berle, 2007). Moreover, natural resource professionals indicate that graduates entering the field require improved plant identification skills (Harrison, 2014). Unfortunately, many students arrive at their discipline with little to no botanical training or experience with important morphological traits useful in identifying plants (Wandersee and Schussler, 2001). Here, we describe our efforts to augment active learning strategies and enhance understanding of key botanical concepts via incorporation of computers equipped with digital microscopes in a plant identification course.

## Procedure

The pedagogical methods referred to as active learning enhance learning and engage students through dynamic, student-centered instruction. Inclusion of these methods boosts understanding and knowledge retention while improving performance on multiple learning assessments (Freeman et al., 2014; Prince, 2004). We applied an active learning framework to engage students in concepts related to leaf and floral morphology and fern reproductive structures (i.e. indusia, sori). Leaf morphological concepts included textures, apices, margins (e.g. complexity, lobing, rolling, dentation), bases, shapes and surface features (e.g. armament, glands, hairs, scales, venation). Floral concepts centered on flower gender and symmetry, insertion of floral parts on the receptacle, and calyx and corolla morphology. We used laboratory fees to purchase fresh cut flowers for all floral activities and razor blades for flower dissection. We utilized purchased flowers to emphasize core concepts rather than demonstrate flowers from class-specific plants. We encouraged students to use microscope image capture and annotation capabilities during all activities. The framework consisted of:

1. *Primary Concept Inventory* – We provided each student with two leaves of six distinct plants from future class periods. We asked students to tape leaves of the same species to one notebook page, and then create a column along the left margin listing concepts described above. Students then created columns labeled “pre” and “post.” We asked students to observe leaves, and then attempt to define each morphological type using their current knowledge and no external sources. We did not require technical definitions. Students worked independently and placed answers on the “pre” list. We employed a similar approach for floral and fern morphology. These activities offer excellent assessments of preliminary knowledge.

2. *Guided Lecture* – We developed guided lectures based on our in-class reviews of primary concept inventories. Invariably, direct teaching methods were necessary at this point. We distributed another set of leaves, or flowers, from about ten distinct species. We randomly grouped students in fours, and each group moved to a designated microscope station. Stations consisted of one digital microscope (T-1050, Ken-A-Vision Inc., Kansas City, MO) and laptop computer (Toshiba Satellite c850) running the microscope software (Applied Vision 4, Ken-A-Vision Inc.). Group members self-selected roles such as microscope operator, software operator, note-taker and spokesperson. We used guided lectures to technically define various morphologies, conduct comparisons, and discuss morphological features. We utilized samples to reinforce important characteristics. Students observed samples with microscopes throughout guided lectures. Groups posted images to an on-line course management system for further discussion. Students then completed their “post” lists. We typically followed guided lectures with a short quiz.

3. *Secondary Concept Inventory* – Students joined their groups to re-evaluate primary inventory samples. We asked group members to compare post-list information then create one master post-list based on agreement of morphological features. Students used microscopes for morphological evaluation. We provided limited instructor intervention and encouraged students to

use their new knowledge in describing morphological features. Groups submitted master post-lists for instructor feedback.

4. *Knowledge Application Activities* – We provided each group with a microscope station, dichotomous keys and identical cuttings from eight distinct plants. Seven plants were identifiable via the keys, but one was not. Students then participated in a contest requiring correct species identification and recognition of the "renegade" species. The first group to provide all correct answers won a prize. This activity concluded with a review of morphological features needed for proper identification. Alternatively, we asked students to use an art form of their choosing to create lessons on floral morphology. We required that floral morphology projects include important morphological topics covered previously, but projects did not need to model a real flower. Students worked on floral lessons individually or in teams of up to three students.

We surveyed students six weeks after the last activity to gain some insight on the value of digital microscopes (Figure 1, Table 1). Surveys occurred during the summer (n = 23 students, n = 20 survey respondents, 87%) and fall (n = 35 students, n = 31 respondents, 89%) of 2014. The University of Florida Institutional Review Board approved the study (UF IRB #2014-U-308) and we provided all participants with written informed consent prior to study participation.

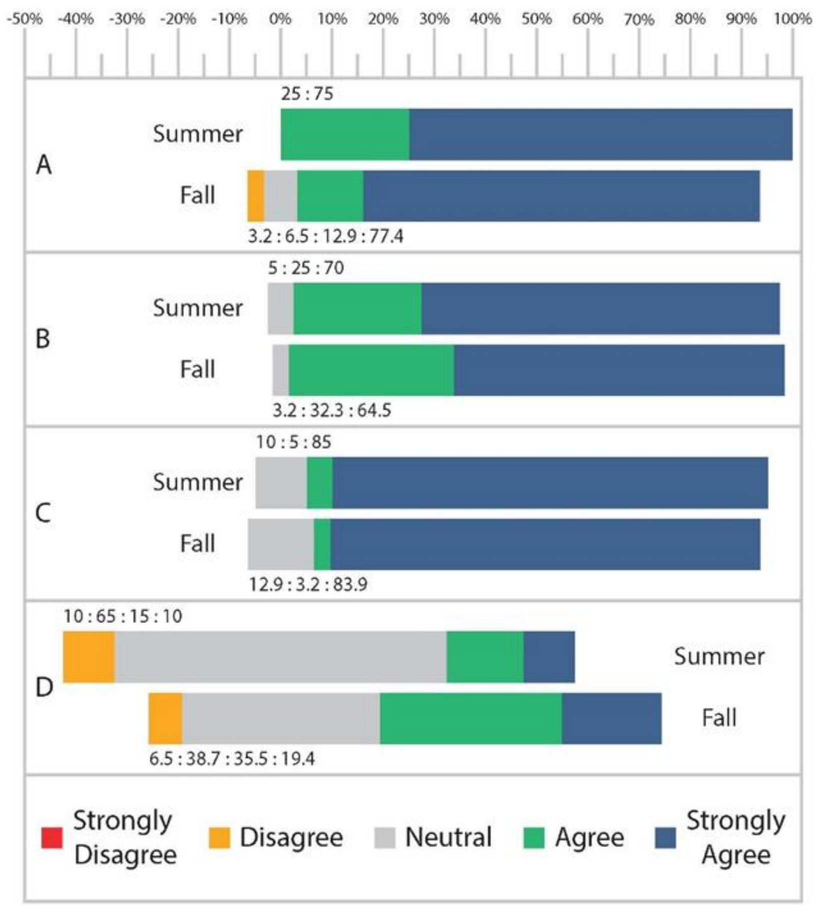


Figure 1. Student level of agreement with survey statements related to the use of digital microscopes in an undergraduate ornamental plant identification course taught during the summer and fall semesters of 2014. Survey statements: (A) The use of digital microscopes improved my understanding of some vegetative and floral morphology concepts; (B) The digital microscopes and software were easy to use; (C) I recommend continued use of digital microscopes in the plant identification class; and (D) Activities with the digital microscopes could be improved. Ratios indicate the percent value for each segment within a bar.

Table 1. Number of student responses to open-ended questions on a survey of digital microscope use in a plant identification course.

| | Summer n (%) | Fall n (%) |
|---|---|---|
| Total number of students responding to survey | 20 (87) | 31 (89) |
| ***How else could microscopes be used?*** | | |
| Number of students responding to open-ended question | 16 (80)[1] | 26 (84)[1] |
| *Categorized student responses* | | |
| More use/more time for activities/more plant materials to observe | 10 (63)[2] | 16 (62)[2] |
| Satisfied with how microscopes were used | 5 (31) | 8 (31) |
| For interactive quizzes | 1 (6) | 0 (0) |
| More zoom capabilities | 0 (0) | 1 (4) |
| Don't know, did not find microscopes useful | 0 (0) | 1 (4) |
| ***How can we improve activities using digital microscopes?*** | | |
| Number of students responding to open-ended question | 13 (65)[1] | 20 (65)[1] |
| *Categorized student responses* | | |
| More use/more time for activities/more plant materials to observe | 7 (54)[2] | 9 (45)[2] |
| Satisfied with how microscopes were used | 2 (15) | 5 (25) |
| Better image quality | 0 (0) | 3 (15) |
| Better instructions on how to use microscopes | 0 (0) | 2 (10) |
| Creating digital portfolios | 0 (0) | 1 (5) |
| Using captured images on quizzes | 1 (8) | 0 (0) |
| Using tools such as forceps for more careful handling of specimens | 1 (8) | 0 (0) |
| Providing a mouse to facilitate software navigation | 1 (8) | 0 (0) |
| Less on-line submission of captured images | 1 (8) | 0 (0) |

[1]Ratio of number of students responding to open-ended question to total number of students responding to survey. Values presented as percentages. Percentages may not add to 100 due to rounding.
[2]Ratio of number of students providing a category specific response to number of students responding to open-ended question. Values presented as percentages.

## Assessment

Figure 1 shows high percentages (87-100%) of respondents agreed and strongly agreed that: digital microscope use improved understanding of plant morphology concepts; microscopes and associated software were easy to use; and continued use of microscopes was warranted. Interestingly, 39 and 65% of students indicated neutrality regarding improvements to microscope activities. Alternatively, smaller percentages agreed or strongly agreed that digital microscope activities needed improvement (Figure 1). We found no difference in student responses between semesters for any survey question ($\chi^2_1 = 2.4$, $p = 0.12$).

Responses to open-ended questions revealed by wide margins that to diversify and improve microscope activities we could: 1) use microscopes more frequently throughout the semester; 2) provide more class time to use microscopes; and 3) furnish more plant materials for analysis. A few students provided other suggestions for overall improvement (Table 1). Additionally, we suggest ensuring adequate classroom lighting, high-quality image projection capabilities, and technical support to maintain software updates. Maintaining updates can be cumbersome for instructors if their institution requires consistent updates to preserve wireless network connectivity.

Try digital microscopes in your class. They enhance student learning and provide the best feedback possible – wonder and delight when studying plant morphology on a finer scale.

## References

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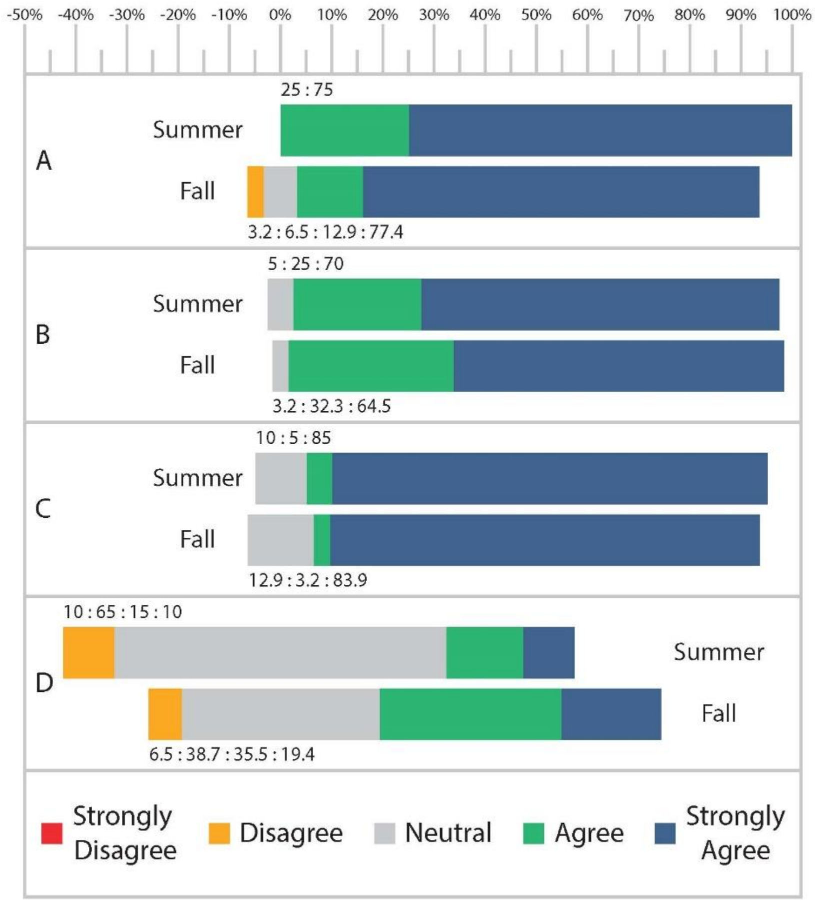
**Figures and Tables**

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