

HERBARIUM SPECIMENS OF
TOXICODENDRON P. MILL. SECTION *TOXICODENDRON*
(ANACARDIACEAE)
AS TOOLS FOR TEACHING
BASIC CONCEPTS IN PLANT TAXONOMY

DAVID S. SENCHINA
Immunobiology Program
Department of Health & Human Performance
283 Forker Building
Iowa State University
Ames, IA 50011-1160
senchina@iastate.edu

ABSTRACT

Four undergraduate-level lesson plans are presented utilizing herbarium specimens of *Toxicodendron* sect. *Toxicodendron* (the poison ivies, oaks, and sumacs) to teach basic concepts of plant taxonomy. The benefits of using this taxon in the post-secondary classroom are discussed. Tables within the text and sub-sections within the lesson plans are provided to assist instructors with integrating these lesson suggestions into their pre-existing curricula.

Members of *Toxicodendron* sect. *Toxicodendron* (the poison ivies, oaks, and sumacs; hereafter abbreviated TST) are found throughout the US (Gillis 1971; Gillis 1975). Currently five species and nine subspecies are recognized. Despite their geographic ubiquity, they are often difficult to recognize in the field due to a variety of factors, including their morphologic plasticity (McNair 1923; Senchina 2003). This has led to discrepancies of opinion amongst amateur and professional botanists alike regarding their identification and classification, as is reflected historically in the scientific literature.

At first these noxious plants may seem unlikely candidates as teaching aids for introducing basic principles of plant taxonomy. However, when used as suggested by the lessons contained in this arti-

cle, they have numerous attributes that make them an excellent model taxon for this purpose. (1) They require students to wrestle with species concepts and subjective differences between species and subspecies, as well as concepts of taxon ranking. (2) They demonstrate some of the difficulties commonly faced by professional botanists ascertaining the systematics of related plants. (3) They demonstrate how these difficulties may translate to confusion or discrepancies of opinion amongst various botanists and the historical impact of such occurrences. (4) They help students come to appreciate what qualities comprise good versus poor herbarium specimens. (5) They force students to grapple with issues of character importance and the realization that a “key character” for one group of plants may be superfluous or misleading for a different group. (6) They help students realize the role that environmental factors (such as soil type, climate, or light exposure [e.g., sun-exposed vs. shade leaves]) or developmental stage (e.g., juvenile vs. mature leaf) may have on the physiognomy of a given individual, and the ramifications of this on plant identification. (7) They provide students with practice in identification of TST, a morphologically variable group with a pan-American distribution.

There are also several logistical (practical) reasons why this taxon is useful in undergraduate courses of plant taxonomy. Colleges and universities with teaching herbaria frequently have a large underutilized collection of these plants, including varieties endemic to areas near the educational institution. (8) Thus, a large sample of specimens from a small, restricted taxon is available to many educators. (9) Safety procedures for using the plant in the classroom are simple. Even though they are geographically widespread and medically important, many people, including students of botany, are often unable to recognize these plants; thus, (10) it is desirable to help growing botanists be able to recognize these economically and socially important plants. (11) TST is a relatively small group with both species and subspecies, making it an ideal size for these educational purposes.

These attributes suggest that TST is a useful instructional taxon for the undergraduate plant systematics classroom. This article presents a series of four lessons demonstrating how herbarium specimens of TST may be utilized to teach basic principles of botanical taxonomy. All four lessons were constructed with a foundation of three underlying goals: (1) utilizing student-based experiential modes of learning to assist students in acquiring basic concepts of plant taxonomy; (2) familiarizing students with TST; and (3) providing students with practice in handling and interpreting herbarium specimens.

MATERIALS & METHODS

Pedagogy

All lessons presented are based on the three-step learning cycle method (Rakow 1986; Colburn & Clough 1997). In this lesson format, the instructional period is divided into three sequential phases: exploration, concept development, and concept application. During exploration, students work with the lesson material as individuals or in small groups without direct instructor involvement. Exploration is student-focused. This phase frequently involves placing students in cognitive “disequilibrium” as they attempt to understand a new concept and assimilate it. In concept development, instructors introduce the main concepts of lesson by utilizing information or insights students gleaned from the exploration phase; this is the main “instruction” part of the lesson and the only teacher-centered phase of the cycle. In the third and final phase, concept application, students apply what they have just learned to a similar (but novel) situation. This student-focused phase frequently provides the instructor with opportunities to formally evaluate the students.

Notes on handling specimens

TST may be safely handled with a few precautions. (1) Treat all specimens as dangerous no matter their age. It has long been known that centuries-old specimens can still cause disease in susceptible individuals (Bogue 1894). (2) Encase specimens in clear plastic display

envelopes (such as those available from Herbarium Supply Co., <http://www.herbariumsupply.com>) for student use. (3) All individuals involved in the lesson should wear protective gloves, even if they claim to be immune. Use cotton or vinyl gloves (the poison actually passes through latex or rubber gloves; Fisher 1996). (4) After returning plants to their respective herbarium cabinets, clean all work surfaces using a 75% or greater ethanol solution and liberal scrubbing.

Instructional materials

All instructional materials needed for a given lesson are listed in their respective lesson plans (see Appendices). Gillis (1971) is recommended for standardizing names of herbarium specimens used in all four activities. Materials needed for extension activities are mentioned within each extension activity separately.

RESULTS

Four lesson plans for undergraduates were included as appendices A-D. Each is organized according to the learning cycle format (see materials & methods) and contains: lesson summary; lesson goals; learning objectives; time required; materials needed; preparation; procedure; discussion and extension activities; and assessment. All lessons are activity- and student-based. Lesson A, “Designing a Dichotomous Key,” shows how the classical dichotomous key construction lesson may be adapted and extended using TST. Lesson B, “Morphological Plasticity in the Genus *Toxicodendron*,” demonstrates the extreme plasticity in this taxon and how this impacts identification and classification; it also addresses species concepts. Lesson C, “Comparing Different Dichotomous Keys,” allows students to compare different keys for the same group (TST) and to weigh the merits of each in relation to the different audiences that each key is targeted toward. Lesson D, “Specimen Identification... Is it Consistent?,” requires students to identify key characters for TST identification and discern qualities of a complete herbarium specimen.

DISCUSSION

While the lessons are presented here as a module, each lesson can be pulled out and used individually and in any order. The discussion and extension activities are assigned to specific lessons but are frequently interchangeable. The amount of preparation needed for each lesson has been minimized to the best extent possible; additionally, materials redundancy was optimized so that materials from one lesson may frequently be employed in another, minimizing preparation time.

The introduction enumerated several reasons why TST was a good model taxon for the educational purposes presented here. To demonstrate how these attributes were utilized in each specific lesson's construction, a table was developed (Table 1) that shows the concordance between each attribute and its utilization within individual lessons. This table is intended to help educators select which lessons to use in their classroom if they desire to teach a particular concept using TST.

To help instructors further integrate these lessons into their current curricula, a second table (Table 2) shows how each lesson and its extension activities pair with specific chapters in two textbooks frequently utilized in undergraduate courses on plant systematics: *Plant Systematics: A Phylogenetic Approach* (Judd et al. 1999) and *Vascular Plant Taxonomy* (Walters & Keil 1996). As the organization and emphases of these two texts differ, one text may be more appropriate for a given lesson than another.

In summary, this paper presents four lesson plans that utilize herbarium specimens of TST to teach basic concepts in plant taxonomy. These lessons embody three overarching goals: (1) to assist students in learning plant systematics by presenting them with activity-based practical exercises; (2) to familiarize students with TST; and (3) to

provide students with practice in working with herbarium specimens. It is hoped that these lessons will be of practical significance in the post-secondary (and perhaps secondary) botany classroom.

TABLE 1. Concordance of TST attributes (as specified in the introduction) to specific lessons (appendices). An "L" indicates that the attribute is utilized in the lesson proper; "E#" indicates that the attribute was utilized in an extension activity where # is the specific number of the activity.

<i>Educational Purposes</i>	<i>Lessons</i>			
	A: Designing a Dichotomous Key	B: Morphological Plasticity	C: Comparing Keys	D: Species Identification
1: Species Concepts		L	E3	L
2: Difficulties Commonly Faced	L	L	L, E3	L
3: Differences of Opinion	L	L	L, E3	
4: Herbarium Specimen Qualities	E1			L
5: Key Characters	E2	L, E1		L, E1
6: Role of Environment	E3	L		
7: Practice in TST Identification	L	L	L	L, E1

TABLE 2. Textbook readings for each lesson or extension activity. Numbers represent chapters; an “A” denotes an appendix. See references for complete citations.

Lesson or Extension Activity	Textbook	
	Judd et al. 1999	Walters & Keil 1996
A: Designing a Dichotomous Key	4, A2	24
A-E1: Using Keys	A2	1
A-E2: General Features TST	4	3, 24
A-E3: Nature Walk		26
B: Morphological Plasticity	4, 6	3, 24, 25
B-E1: Concept Elaboration		21
B-E2: Tools of the Trade	1, 2, 5	23
B-E3: Role of Genetics	2, 5	25
C: Comparing Keys	A2	1, 4
C-E1: Modifying a Key	A2	4
C-E2: Keys Non-Botanists	A2	4
C-E3: Synonyms	A1	2
D: Species Identification	4	3, 4
D-E1: Difficulties of Class	2, 3	22
D-E2: Correcting Specimens	A1, A2	2, 26
D-E3: Plant Collecting	A2	6, 26
D-E4: Herbarium Organization	A2	6, 26

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APPENDIX A

Lesson A: Designing a Dichotomous Key

Summary: Students will learn the basic elements of dichotomous keys and, in small groups, design a dichotomous key for a collection of TST herbarium specimens.

Goals: A. Students will be able to describe the general format of a dichotomous key. B. Students will be able to construct a key for a group of labeled herbarium specimens. C. Students will better understand some of the key features of TST.

Objectives:

1. Students will describe verbally or in writing at least four features of a dichotomous key.
2. Working in small groups, students will construct a dichotomous key for a group of no fewer than five TST taxa.

Time Required: ~90 minutes

Materials Needed:

- herbarium specimens of TST (see Preparation)
- collection of dichotomous keys for any taxa
- chalkboard, greaseboard, opaque projector, or similar device
- cotton or vinyl gloves
- paper and pencil per student

Preparation:

1. Decide in advance into how many small working groups you will divide the class. If supplies are few and the class is small, this activity may be conducted as a large group.
2. Organize one to two herbarium specimens each of five distinct TST taxa that are identified according to a standard scheme (for example, Gillis 1971) for each working group. Species, subspecies, or a mixture may be used for taxa. Include specimens with

flowers or drupes wherever possible. Segregate herbarium sheets into groups ready for distribution once the lesson starts.

3. Assemble a collection of dichotomous keys for any taxa from field guides, manuscripts, monographs, or other sources. Have at least two keys for every working group.

Procedure:

Exploration (20-25 minutes)

1. Explain to students that in this lesson they will be constructing dichotomous keys for plant identification.
2. Ask students to consider the properties of a dichotomous key based on their past experiences. Some guiding questions may include: What do they look like? How are they formatted? How are they worded? How many steps do they have?
3. Divide the class into small groups (two to three students per group). Instruct groups to make a list of the properties they uncover. Show students the dichotomous key collection and encourage them to examine these keys for ideas. Let the students take no more than two keys at a time back to their small groups.
4. Circulate around the room but provide as little guidance as possible during work time. Ask guiding questions to student groups that struggle.
5. Stop group work. Bring all students back to the large group for discussion.
6. Solicit a list of what students believe are the general features/properties of dichotomous keys. Base this list entirely on student observations and discoveries. Write the list on the blackboard or other medium. Accept all observations at this time, whether correct or not (we will fix any errors in the following section). Do not allow students to criticize other students' observations.

Concept Development (15-20 minutes)

7. Allow the class to debate the list generated above. Allow students to challenge any item on the list, but only by citing a reason based upon personal observation. Make changes to the list only

when the majority of students feel the change is valid. Moderate the debate until the class is satisfied with their list.

8. Share your own comments about the list only after the class is finished. Point out features that you agree or disagree with and explain why. Examples: each step has two choices (break down the word "dichotomous"); the number of steps is n-1 the number of taxa; etc. Sculpt this list into a finalized format that students may write in their notes (see step #10).
9. Ask students if there were any ways dichotomous keys varied (what were *not* properties of a dichotomous key but simply formatting preferences)? Example: indenting steps of the key versus using a bracket method as in *Vulpia*.
10. Ask students to write down the list individually.

Concept Application (30-40 minutes)

11. Explain to students that they will now construct their own key for a group of five different taxa of TST. Provide an introduction to the taxa as is appropriate to the class.
12. Introduce or review safety procedures for working with herbarium specimens of TST. Example: gloves should be worn when handling specimens but not when writing (to prevent transfer of the poisonous element). Clarify how these procedures will apply to the activity at hand. Example: small groups may wish to designate one individual to only write and not touch the specimens; this person should still participate in specimen examination. At the end of activity, students who were writing can exchange information with those who were not.
13. Distribute specimens to all groups. Allow for work time.
14. Stop group work. Tell student groups to leave their keys at their station and rotate to a different group's station. Have groups evaluate each other's keys by trying out the key. Encourage exchange of student suggestions through writing.
15. Allow an appropriate amount of time for groups to read suggestions and alter their keys.
16. Collect keys for evaluation.

Discussion & Extension Activities:

1. Using Keys (5-10 minutes) – Ask students what was easy and what was difficult about constructing the key. What challenges did they encounter? How were these challenges overcome? Does anyone have solutions, tricks, or insights to share with the rest of the class? How did the quality of herbarium specimens impact their ability to use the key?
2. General Features of Poison Ivy (5-10 minutes) – Ask students to generate a casual description of TST based on their experiences in this lesson. How can it be identified in the field? How does it differ from other similarly looking plants? What characters proved most useful in discriminating between taxa? Which characters were variable and not informative?
3. Nature Walk – Have students be on the lookout for TST during class field trips. How did the students identify it (what made it distinct from other plants around it)? How does the local environment impact TST physiognomy?

Assessment:

Assess objective #1 informally by circulating between groups and surveying their notes. Alternatively: collect their notes and evaluate outside of class. Assess objective #2 more formally by collecting student keys and evaluating them outside of class. Alternatively: give individual students or groups of students another batch of plants (either live or pressed) and have them design a second key.

APPENDIX B

Lesson B: Morphological Plasticity in the Genus *Toxicodendron*

Summary: In this activity, students objectively characterize the extent of variation among leaf and habit characteristics for multiple subspecies of *Toxicodendron radicans* (eastern poison ivy) and discuss the implications of this plasticity for taxonomy.

Goals: A. Students will measure multiple morphological characteristics of poison ivy subspecies and determine which features are more useful in classification than others. B. Students will discuss implications of morphological plasticity in terms of classification and taxon ranking. C. Students will better understand multiple species concepts.

Objectives:

1. Given a pre-selected collection of TST herbarium specimens, student groups will measure and record data on various leaf, flower, and habit characteristics as specified in the accompanying worksheet.
2. From #1, student groups will determine (based on their collective opinion) whether the collection represents one, two, or three TST taxa and will be able to explain two specific reasons for their choice.
3. Individually, students will be able to explain in writing why two different botanists may systematically treat the same groups of plant differently by citing at least two specific plausible explanations.
4. Students should be able to name at least three distinct species concepts and verbally define all three correctly.

Time Required: 120 minutes

Materials Needed:

-one copy of Gillis (1971, pp. 163-164) (see reference for com-

plete citation) per group

-herbarium specimens of *Toxicodendron radicans* (see Preparation)

-paper clips (at least two per specimen)

-heavy cardstock

-chalkboard, greaseboard, opaque projector, or similar device

-cotton or vinyl gloves

-paper and pencil per student

Preparation:

1. Examine your college's or university's collection of *T. radicans* herbarium samples (or another TST species more heavily represented in your herbarium). Select ten to twelve specimens from the same subspecies for each group (the subspecies selected need not be the same for each group; it is actually desirable if each group has a different subspecies); set aside. Each group's collection should be as diverse as possible. Clip a card made of heavy cardstock over each specimen's label so it cannot be read.
2. Xerox one copy of Gillis' key (see Materials above) per group. Appendices C & D also use this key. Also photocopy the worksheet "How Many Species?" (included in this lesson plan) once for each student.
3. Set up the classroom before students arrive. Organize all materials for groups as stations: one set of herbarium specimens (as in step #1 before), rulers, and copies of the "How Many Species?" worksheet.

Procedure:

Exploration (60-90 minutes)

1. Ask students, "What is a species?" Write all student comments, regardless of correctness, on the board.
2. Continue by asking, "What's a subspecies? Or a variety? How about a cultivar?" Allow students to debate among themselves if they wish, but don't interject any views of your own. Again

write student opinions of each on the board. Allow students to revise their opinions during the discussion if they wish.

3. Explain to students that in the next activity, they are going to examine a group of unnamed (masked label) plants and determine if their collection represents one, two, or three species. [It is better to limit their choices to "one, two, or three species" rather than say "any number of species" or "any number of species and subspecies" or students may see the task as overwhelming.]
4. Organize students into working groups and assign each group to one station (see Preparation, step #3 above).
5. Go over the directions for completing the worksheet with the students: Several characteristics are listed (see columns). For each herbarium specimen (rows), simply fill in the blank with the requested information. Example: for leaflet width, find an "average" leaflet, measure its width, and record your observations in the row designated for that specimen. If there is much variation in the specimen, write a range instead. Do this for all specimens. Afterwards, look at your results as a group, and decide whether your collection represents one, two, or three species. [This is an excellent opportunity for students to practice their vegetative terminology.]
6. Introduce or review safety procedures for working with herbarium specimens of TST (see Appendix A, step #12).
7. Allow for work time. Circulate and assist as necessary. Differences in opinions among group members must be resolved within the group without help from the instructor.
8. Continue circulating and stimulating group thinking by asking questions but do not directly offer opinions as groups transition into discussing their results.
9. Stop group work when you notice that groups have determined their number of taxa. Give each group a blank sheet of paper. Direct them to write "1," "2," or "3" as a large numeral at the top and provide a short sentence describing two specific reasons for why they arrived at this decision.
10. Leave papers at their respective stations. Have students rotate

around the room and look at what other groups wrote to see how other students tackled the problem.

- Optional: Moderate a group discussion where student groups share any difficulties they faced, such as whether there was a conflict of opinion between group members, why there was this conflict, and how it was resolved (if it was).

Concept Development (20 minutes)

- Students are likely anxious to know what the “correct” answer is for their group. Announce that there was one species at each station. Encourage them to remove the cards and read the labels for themselves. Surprise students by saying each station had the *same* species! Elaborate on details if different or same subspecies were used between stations. Discuss the students’ reactions with them. Are they surprised or not? Why? Emphasize that this “correct” answer is based on one botanist’s professional opinion (Gillis 1971), but that the majority of other botanists have supported his organization.
- Discuss: What could account for such tremendous variation within a single species? Record student responses on the board. What environmental factors might influence the form of a plant? How might two botanists interpret this variation differently?
- Review with students the difficulties they faced during the activity. Were any of these difficulties related to the definition of what a species is?
- Introduce the term “species concept,” explain what is meant by it, and give examples of several different species concepts (these will differ by instructor preference). Use the chalkboard to record the main points you’d like to convey to students. Connect back to what students brainstormed in the “exploration” phase as much as possible in your discussion.
- Continue by discussing differences in the terms subspecies, varieties, and cultivars. Use the herbarium specimens in the stations as visual aids during your discussion.

Concept Application (15 minutes)

- Pose this question to students: “Now that you know the names of several species concepts, which species concepts did your group employ to determine how many species were in your collection?”
- Allow time for groups to discuss. [The most applicable answers are along the lines of the diagnosability and phenetic species concepts sensu Judd et al. (1999) Table 6.4.] Instruct students to write down their answer on the back of their worksheets.
- Ask students to answer the following second question individually, also in writing on the back of their worksheet: “Based on your experiences today, explain in writing how two different botanists looking at one of these groups of plants might come up with two different classification schemes. Give at least two possible explanations.”

Discussion & Extension Activities:

- Concept Elaboration (variable timing) – Discuss other closely related concepts and their terminology. Example: the difference between *a priori* (artificial) and *a posteriori* (phenetic) classification schemes (between steps #15 and #16) or the concept of qualitative and quantitative characters (between steps #5 and #6).
- Tools of the Trade (60 minutes) – Several computer programs are now available to analyze morphologic and/or genetic data cladistically. Demonstrate how to use one such program for the students. Instruct students to generate a cladogram using the data from this lesson’s worksheet (or a different data set, which may include genetic traits).
- Role of Genetics (30 minutes) – Until recently, classification of plants was based largely on physical traits. However, physical traits may be misleading for a number of reasons. Based on their experiences in this lesson, have students postulate what some of these reasons may be. Supplement their answers with observa-

APPENDIX C

Lesson C: Comparing Different Dichotomous Keys

Summary: In this lesson, students compare dichotomous keys for TST taxa as authored by different investigators. The advantages, disadvantages, and potential misgivings of each system are discussed.

Goals: A. Students will understand that there are multiple valid ways to design a dichotomous key for the same group of plants.
B. Students will compare different keys to one another and discern benefits or drawbacks between them.

Objectives:

1. Students will verbally explain at least two ways that two different botanists could design different but equally valid dichotomous keys for the same group of plants.
2. Using two separate and distinct keys for the same group of plants, students will identify three or more distinct characteristics that made one key better or worse than another (for a given audience) in writing.

Time Required: ~60 minutes

Materials Needed:

- one copy of each of the following keys per student working group:
 - Frankel (1991, p. 92) (see References for complete citation)
 - Gillis (1971, pp. 163-164) (see References for complete citation)
- correctly identified herbarium specimens of TST (one specimen of as many different taxa as possible)
- cotton or vinyl gloves
- chalkboard, greaseboard, opaque projector, or similar device

-paper and pencil per student

Preparation:

1. Photocopy and assemble in manila folders one set of keys as described above for each group of two to three students. Appendices B & D also use copies of Gillis' key.
2. Make a collection of one herbarium sheet for as many different TST taxa as your herbarium allows for each group. Segregate into piles for easy distribution.

*Procedure:***Exploration (10 minutes)**

1. Explain to students that in today's lesson they will evaluate different, distinct keys for the same groups of plants and discern advantages and disadvantages of each.
2. Distribute copies of the keys to each group. Direct students to scrutinize the keys (without using any herbarium specimens) and make preliminary assessments of each within their small groups via discussion. Encourage them to cite specific reasons for their preferences.
3. Brainstorm on the blackboard what students liked or disliked about the keys as a large group. This list should come wholly from the students and not include any insights from the instructor.

Concept Development (25-30 minutes)

4. Introduce or review safety procedures for working with herbarium specimens of TST (see Appendix A, step #12).
5. Distribute herbarium specimens to the class and have them, in small groups, try out each key on three to four specimens. After trying out BOTH keys, instruct students to write down (either individually or as a group, your preference) three specific reasons why they liked or disliked one key compared to another. They may also list favorable or unfavorable attributes.
6. Bring the class together and solicit opinions from individual

groups as to the qualities of both keys. After each opinion, ask other groups in the class for their reaction. Encourage students to discuss why they had different opinions. Intercalate your own observations.

7. During the discussion, make a table on the board as diagrammed below. Use this table to compare characteristics of the two keys. For each characteristic, put a checkmark under the author's name if their key exemplified that characteristic. Place a dot under the author's name if their key lacked that attribute. [Please note that the lack of a given attribute (i.e., confusing jargon) may be beneficial, and hence plus and minus signs are not recommended for this table.]

	Frankel (1991)	Gillis (1971)
Characteristic #1		
Characteristic #2		
Characteristic #3 (and so on)		

8. Ask: "Which key is correct?" Students will quickly respond that both may be valid keys in the appropriate circumstances. Lead them to the following question if their discussion did not reach the question on its own: How does the intended audience of a key determine the quality of the key? Referring to Frankel's and Gillis' keys, are they intended for similar or different audiences? How do you know? Are both valid? Relate your discussion back to the class' chart. Likely students will have opposing viewpoints on some items.

Concept Application (15-20 minutes)

9. Write the names of the following three potential audiences on the board: sixth grade student, twenty-year-old amateur naturalist, and fifty-year-old professional botanist.
10. Direct students to determine which key is best for each audience

in their small groups. Students should cite three specific reasons why they made their selection for each person.

11. Collect student papers from action #9 above.

Discussion & Extension Activities:

1. Modifying a Key (30 minutes) – Ask students to design a hybrid key for the twenty-year-old amateur naturalist in small groups. They may modify Frankel's and Gillis' key "up" or "down" in technicality, or generate an entirely new key. Afterwards, have students circulate around the room and view each other's keys. Ask: Did everyone make the same adjustments, or were there multiple solutions? What modifications were made?
2. Designing Keys for Non-Botanical Audiences (10 minutes) – Discuss as a group which features of the plant were most useful for identification. Keep the audience in mind – are some features useful for one audience, but not as useful or possibly confusing for another? How simplified can a key become before it's misleading? What is an acceptable level of simplification? These are questions that amateur and professional botanists alike encounter when designing keys for audiences outside of botany.
3. Synonyms (15 minutes) – Discuss how the existence of multiple keys for a given taxon perpetuates the use of different names (synonyms) for the same entity. Explore this issue in the context of regional or local keys. Introduce the Integrated Taxonomic Information System (ITIS, <http://www.itis.usda.gov/>). Help students explore this database themselves using a computer lab and the plant kingdom search term "Toxicodendron." How do national databases such as ITIS help manage synonyms?

Assessment:

Assess objective #1 informally during action #8 above and during other discussions. Assess objective #2 formally by collecting student papers from the concept application phase.

APPENDIX D

Lesson D: Specimen Identification...Is it Consistent?

Summary: Morphological variability in TST often leads to inconsistent identification. In this double learning cycle exercise, students evaluate their educational institution's herbarium collection of *Toxicodendron radicans* (eastern poison ivy) for consistent identification.

Goals: A. Students will identify aspects of TST biology that make it difficult to describe and identify. B. Students will evaluate their school's collection of TST specimens. C. Students will understand better what qualities constitute a good versus a poor herbarium specimen.

Objectives:

1. Students will sort through a selection of no less than five herbarium specimens of TST and pick out inconsistent identifications in at least fifty percent of all such instances using the dichotomous key produced by Gillis (1971).
2. Students will name verbally no fewer than four characteristics that differentiate a good herbarium specimen from a poor one.

Time Required: ~75 minutes

Materials Needed:

- one copy of Gillis (1971, pp. 163-164) (see References for complete citation) per group
- herbarium specimens of *Toxicodendron radicans* (see Preparation)
- chalkboard, greaseboard, opaque projector, or similar device
- cotton or vinyl gloves
- paper and pencil per student

Preparation:

1. Examine your college's or university's collection of *T. radicans* herbarium samples (or another TST species more heavily represented in your herbarium) prior to class. Check for any inconsistent identifications (sensu Gillis 1971), which may be more common in student-produced herbaria versus research herbaria (for examples of common errors, see Frankel 1991 and McGovern et al. 2000). Select both consistently and inconsistently identified specimens, for a combined total of six specimens per group with one or two inconsistent specimens. Organize for ready for distribution. Alternative: Take consistently labeled *T. radicans* sheets and paper clip a heavy paper card over all labels. Write the correct name on a majority of the specimens, but for one or two write an incorrect name. Remove cards at the end of the exercise. Alternative: use non-TST look-alikes (such as *Acer negundo*, *Hedera helix*, or *Staphylea trifolia*) and label them as *T. radicans*.
2. Save two or three consistently identified specimens for instructional purposes.
3. Xerox one copy of Gillis' key (see Materials above) per group. Appendices B & C also use this same key.

*Procedure:***Exploration, Cycle 1 (10 minutes)**

1. Tell students that in today's lesson they will examine herbarium specimens that are purportedly *T. radicans* (or whichever taxon you chose) and determine which are consistently or inconsistently identified according to one classification scheme (Gillis 1971).
2. Organize students into small groups. Distribute sorted specimen collections. Introduce or review safety procedures for working with herbarium specimens of TST (see Appendix A, step #12). Instruct students to examine specimens without the aid of keys. Ask them to make preliminary guesses as to which specimens are consistently identified as small groups. Offer no guidance at

this time.

Concept Development, Cycle 1 (15-20 minutes)

3. Distribute copies of Gillis' key (see Materials above) to student groups. Instruct students to peruse the key and determine key characters for differentiating *T. radicans* from other TST taxa (without using specimens). Alternative: Simplify this exercise by having them first identify the characteristics for a single or subgroup of subspecies. Some students may perceive the task as daunting and require additional guidance. See Gillis (1971, pp. 186-187) for further details.
4. Generate a list of key characters on the blackboard based on the views of the large group. Coach and adjust as necessary.
5. Ask the class to pick out three or four most important characters. Place a star next to these.
6. Point out these key characters using the two or three specimens you set aside during preparation. If a key character can't be seen on the sheet (due to poor mounting or lack of material), discuss this also.

Concept Application, Cycle 1 (30-45 minutes)

7. Instruct students to determine consistent or inconsistent identification of their specimens in their small groups using Gillis' (1971) key.
8. Circulate around the room providing guidance as needed.
9. Instruct groups to notify you when finished. Examine group results and give appropriate feedback. For inconsistently identified specimens, have groups determine whether the specimen is a TST or non-TST member.

Exploration, Cycle 2 (10 minutes)

[After finishing the first learning cycle (actions #1-9 above), immediately proceed to this second learning cycle. It flows seamlessly from the first.]

10. Lead a class discussion regarding the difficulties faced in completing the task. What was hard or easy? Which specimens were

easier to use than others? Why?

11. Direct students to rank how easy each herbarium sheet was to use their small groups. Suggest a scheme ranging from one (difficult) to five (excellent). Ask student groups to generate a list of specimen qualities that were helpful in identification.

Concept Development, Cycle 2 (10 minutes)

12. Reconvene the large group. On the blackboard generate a list of qualities from action #11. Discuss what properties the "perfect herbarium specimen" *T. radicans* would have.
13. Assist students in expanding their list with prompting questions. Examples: What plant parts would be included (roots, stems, leaves, flowers, fruit)? Would it be possible to find a single specimen both fruiting and flowering (for poison ivy, this would be highly improbable)? How would the leaves be arranged on the sheet? Would some be obverse and others reverse? Why is thorough labeling so critical? What if the specimen was too long to fit on the sheet without bending? You can use this time to introduce many ideas about plant pressing, drying, and mounting; you could also model plant collecting using a more benign plant (as suggested in Discussion/Extension activity #1 below).

Concept Application, Cycle 2 (15 minutes)

14. Direct student groups to write a formal list of the characteristics that a perfect herbarium sheet, for any plant species, would embody. Encourage them to think about this list in the context of their own plant collecting endeavors. Inform groups to design their lists suitable for photocopying and distributing to the rest of the class.
15. Circulate around the room and assist as needed.
16. Instruct student groups to make enough photocopies of their lists for all students in the class, to be distributed next class session.
17. Encourage students to apply this knowledge when making their herbarium collections (or assign them to collect one plant of any species and generate the "perfect herbarium specimen" using it).

Discussion & Extension Activities:

1. Difficulties of Identification (10 minutes) – Lead a class discussion on characteristics of TST taxa that might make them difficult to classify. What role can proper specimen preparation play in overcoming such barriers?
2. Correcting Specimen Sheet Misidentifications (5 minutes) – Demonstrate how a visiting botanist might annotate an herbarium sheet if s/he feels the label on the specimen is incorrect. Show several examples from herbarium sheets.
3. Modeling Plant Collection and Herbarium Specimen Formation (20-30 minutes) – Demonstrate for students the construction of a plant press and proper technique for harvesting and drying specimens. Proceed to a demonstration of mounting and label preparation methods.
4. Herbarium Organization (15-20 minutes) – Conduct a tour of your school's herbarium, showing how taxa are arranged. Discuss the advantages and disadvantages of your school's particular organizational scheme. Where are the TST specimens? What are some other closely related taxa? What familiar or economically important plants are closely related?

Assessment:

Assess objective #1 during actions #8-9. Use formal or informal scoring per your preference. Assess objective #2 from the result of action #16, which students turn in at the start of the next class session.