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A Lesson on The Scientific Method Using Termite Behavior

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In this guided-inquiry laboratory exercise, students observe a striking termite behavior; termites will follow an ink line, but not one drawn with a pencil. The students generate hypotheses, manipulate variables, collect data, and use statistical analysis to support or refute their hypotheses about termite behavior. Over the following week or so, students work collaboratively to create a presentation of their findings, present them to the class, and participate in peer review of their work using a web-accessible rubric (e.g. Google Doc) during the presentations. Typically, students use their handheld smart devices (e.g. cell phone, tablet, notebook and laptop computers, etc.) to take pictures and record video of the experiment. Presentations are cataloged, stored, and made available to students for future reference using a Learning Management System (LMS) (e.g. Moodle), and is part of their ePortfolio of undergraduate work. This activity is intended for general education students at the freshman or sophomore level, and perhaps biology majors early in their program of study. It can be completed in two, two-hour lab periods. Although the internet is replete with this termite experiment, the activity presented here combines statistical analysis to support claims made about this phenomenon.

Keywords: active learning, scientific method, termite, behavior, peer review, Moodle, guided inquiry

Introduction

When students observe termites following an ink line on paper (an in-class demonstration), it naturally stimulates them to question why almost immediately. At this point, they have already experienced two steps of the scientific method: observe and question. Perhaps unbeknownst to them is that the solvents in the ink are very similar to the pheromones of the queen termite. Hypotheses start to flow freely from students, and then I will randomly assign them to collaborate with a partner for this project. I encourage them to work out the experimental design with their partner over the next week or so, and when they come back to lab they are ready to implement their plan.

With a bit of information, redirection, and probing from me, they begin to identify ways to measure the phenomenon (e.g. time on station, length of deviation from the line, frequency of deviations, etc.). Most groups have a research plan that includes the manipulation of variables with low-tech materials and ideas I make readily available to them in the lab (e.g. pen color, pen type, pen brand, paper type, paper color, line width, curve lines vs. straight, etc.). Other than the collection or purchasing of termites, this lab can be carried out well within a typical biology lab period (e.g. two to three hours) to collect data. Over the next week or so, the students analyze the data, draw conclusions, and crate their presentation (e.g. Prezi, PowerPoint, etc.). At the next lab meeting, students then present their findings to the class.

Leading up to my in-class demonstration of this odd termite behavior, they have already used two statistical tests which arm them with the analysis tools necessary to support or refute hypotheses: means testing using analysis of variance ANOVA ("ANOVA: single factor," in MS Excel) and linear regression ("regression," in MS Excel). Sample size is a topic of discussion for the purpose of getting a reliable representation of the population, and not to determine universally what the sample size should be. This is a quick and effective introduction to, and application of, the scientific method and the application of statistical tests to offer evidence, not a treatise on proper statistical confidence of sample size. However, this has generated teachable moments on time, effort, and the cost of experimentation; researchers face these constraints routinely. In this case, cost is minimal for the student researchers since they are using readily available materials found at most campus bookstores (e.g. pens, paper, etc.); however, time is limited to a lab period or two.

I have found five to seven replications per treatment works well, and it too will vary depending on the statistical test (e.g. simple linear regression, analysis of variance, etc.). These statistical tests are very approachable for college students using MS Excel when examples are provided in class, and MS Office is available on most campuses, usually at a reduced rate if not free.

Learning Objectives

After completion of the laboratory exercises, Students will accomplish the following learning objectives:

- Observe natural behavior of living organisms (termites)
- Design and manipulate variables of an experiment
- Pose and test tentative hypotheses
- Statistically analyze the data
- Evaluate the statistical significance of the data
- Create an oral presentation of their findings
- Present their findings to their peers
- Participate in peer review of all peer presentations

Time Requirements

Once termites have been obtained and given to the students, the observation, question, hypothesis, testing, and data collection can been completed well within a typical college lab period, approximately two hours. With the remaining time, I go over the scoring rubric and make a copy available to them on the LMS (e.g. Moodle, D2L, Blackboard, etc.) to use immediately following each presentation. Occasionally, I have allowed the class to discuss relevant criteria for the rubric, and have allowed them to take part in its creation. Typically, the scoring rubric includes the following:

- How clearly is the hypothesis stated?
- How appropriate is the experimental design to the constraints of lab space, equipment, and time?
- How appropriate is the statistical analysis?
- How well are the conclusions supported by the statistical analysis?
- How well did the presentation conform to the 10-minute time limit?
- How well did the presentation follow logically?

Over the next week, students statistically analyze their data, collaborate on creating their oral presentation, and ideally, will rehearse their presentation. This process takes about two to three hours. At the next weekly lab period meeting, students present their findings in class, and the presentations are scored. Ten minutes is enough time for students to present their work. I suggest a time limit of 10 minutes be included as part of the scoring rubric to allow all groups to present within the lab period.

As far as scoring goes, I will score them, the class will score them, and the partners within each group will score themselves. This allows three “lenses” with which the project is scored and averaged for their presentation grade. The scale used for scoring all three so-called lenses is one with which they are familiar: A, B, C, D, and F, for each category on the rubric. I use a grade point to numerical conversion chart to convert the final average to a percentage grade (Appendix 1). Since the scoring from me and the class is completed and submitted online using an internet capable device immediately following each presentation, all that remains for their grade is the partners to score themselves. This is done in class in separate areas of the room, and this is the only aspect of their grade the student groups will not see so intellectual safety can remain intact.

Storing and Cataloging Presentations

For cataloging and storing their presentations, I have found it very helpful to create a Prezi (www.prezi.com) document on my account and allow each group editing access by sending the information to their secured school email accounts. Prezi is a robust presentation platform which allows asynchronous collaboration among partners, seamless integration of pictures, sound, and video like YouTube and other web URLs. By allowing students to create the content, it empowers them to be more involved with the scientific process rather than merely searching for a site from which to “get the right answer.” Because their presentations are stored and cataloged automatically on my Prezi account, they are available for me to post on the Moodle LMS for future student review at my discretion. Further, this can now become part of the student’s ePortfolio, a feature that is fast becoming a way to demonstrate student achievement. Besides, it then becomes very unlikely their work will be unavailable because a partner “forgot to bring their flash drive to class,” among other incredulous excuses.

Student Outline

I have found it more engaging for students if they are given a very brief verbal introduction and minimal instructions rather than distributing a detailed handout for the activity. This approach also speaks to the types of activities supported by Vision and Change in undergraduate biology education: a call to action (AAAS, 2010). Having students observe the ink-following behavior of termites engages them immediately and effectively without having to follow a sequence of steps to arrive there as in typical cookbook style lab exercises. Although I demonstrate this for the students using a document camera connected to a projector, student may perform the following at their lab bench:

1. Obtain a small paint brush, two 8.5 x 11 inch sheets of plain white copy paper, and one termite.
2. Draw a circle approximately 13 cm in diameter in the center of the page using a pencil.
3. Place the termite in the center of the circle, and observe its behavior for one minute.
4. Draw a circle approximately 13 cm in diameter in the center of the page using an ink pen.
5. Place the termite in the center of the circle, and observe its behavior for one minute.
6. Compare and contrast the termite behavior observed on the pencil circle and the ink circle.

Materials

Each group of two students will need the following materials:

- Approximately 5 to 8 termites initially, more may be required depending on experimental design
- One to two small paint brushes for the purpose of handling the termites on the paper
- One standard lunch tray (plastic or metal)
- Moist paper towels to lay over the termites and wood (this also helps isolate the termites because they are attracted to the moist paper towel, and away from the wood particles)
- Standard multipurpose copy paper (8.5 x 11 inches)
- Access to various colored pens, colored pencils, markers, and perhaps even chalk
- Wall clock, or digital timer, perhaps a ruler, and even a hand lens would be useful
- Other items available in the lab to make barriers, fashion paper apparatus, like tape, scissors, paper clips, etc.

Instructor Materials

Although termites are available from biological supply houses (Appendix 2), and are sometimes packaged together with other materials as a demonstration kit (Appendix 2), they are easily collected from their natural habitat. In most temperate regions of the world, particularly in mixed deciduous forests, termites inhabit deadfall; given a choice, subterranean termites prefer pine over most hardwoods. Using a hatchet with moderate force to break into the fallen logs, termites can be revealed and collected (Fig. 1). They may be placed with pieces of log into large plastic lawn bags for transport to the lab.

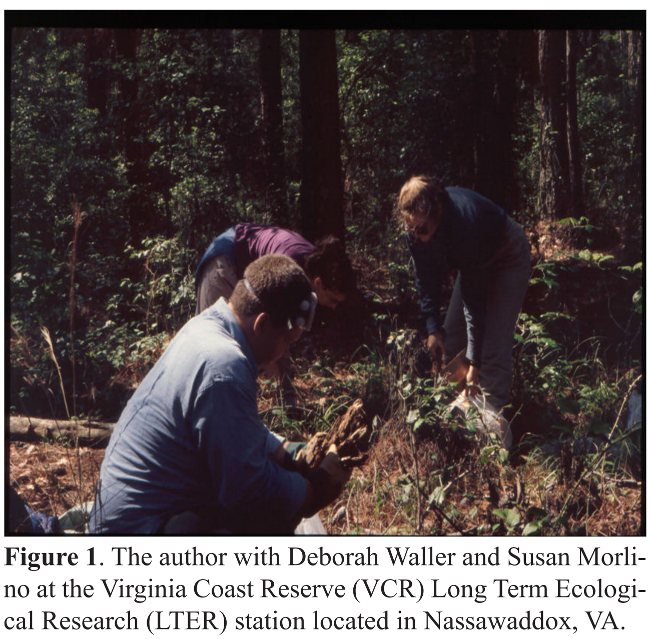

Figure 1. The author with Deborah Waller and Susan Morlino at the Virginia Coast Reserve (VCR) Long Term Ecological Research (LTER) station located in Nassawaddox, VA.

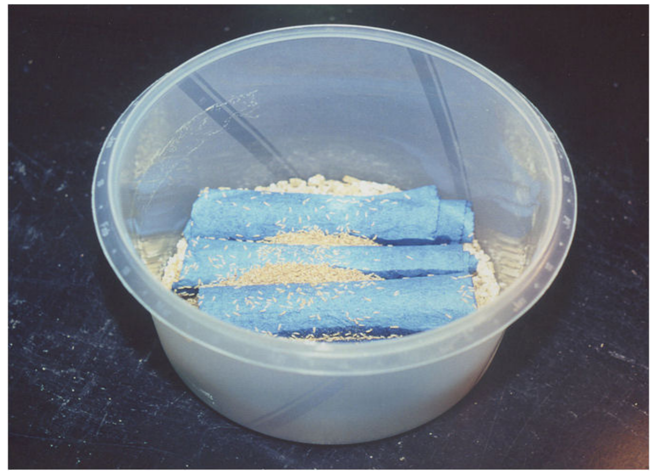

Figure 2. Termites shown with dyed paper towels on a layer of vermiculite in a 1-gallon plastic storage container for long term storage in the lab (months). Note: The container's lid with ventilation holes is not shown, and the paper towels need not be dyed.

On the day of the exercise, placing a sheet of paper on a document camera (if available), drawing approximately a 15 mm diameter circle with a pencil, and then placing several termites on the paper to observe termite behavior makes a great demonstration when compared to the ball-point pen circle. Termites will not follow the pencil line, only the pen line. If a document camera is not available, then have the students do this as part of your verbal instructions to them. Either way is effective.

From this point forward, move around the room and visit the student groups to guide their inquiry. You do not need to be a termite biology expert to get the students started. Having access to the internet may prove valuable to vet queries as they arise.

Safety

Subterranean termites are dependent on soil moisture for survival in the wild. In the laboratory setting, they need to be supplied with a source of water, hence the purpose of the moist paper towels. However, laboratory-maintained termite colonies pose no credible threat to people, lab equipment, or the building in which they are housed. However, the termites should be manipulated using small paint brushes rather than handled directly because they are very fragile and are damaged easily without such precaution.

Once collected from the field or purchased from a biological supply house, termites can be maintained in the lab for months, perhaps even years with enough food (wood or filter paper) and water (moist paper towels on top of a one- or two-inch layer of vermiculite) if kept in a sealable container (Fig. 2) with ventilation holes (Curtis and Waller, 1995). Sections of logs heavily infested with termites (tens of thousands of individuals) can be placed in large plastic lawn bags, loosely tied, and placed in 29-gallon galvanized steel garbage cans (Fig. 3) with their lids for months (Curtis and Waller, 1997).

Figure 3. Large sections of termite-infested logs placed in loosely-tied large plastic lawn bags stored in 29-gallon galvanized steel garbage cans for long term storage in the lab (months to years).

Termite Behavior Videos on the Internet

There a many videos on the internet that depict this ink-line-following behavior of termites. The difference in this activity is that students can use what they have learned about statistics to provide evidence to refute or support their claims. Either by generating their own hypotheses, or by testing the claims of other termite behavior experiments available to them on the world wide web, students are able to apply their knowledge of evidence-based claims in way that is acceptable to scientists, by statistical analysis.

Acknowledgements

I thank Dr. Deborah Waller for mentioning this termite behavior to me when I was a grad student of hers at Old Dominion University. It has been a gateway through which many of my students have learned and continue to learn the scientific method, experimental design, and basic statistical analysis.

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About the Author

Anthony Curtis earned his B.S. and M.S. in Biology from Virginia Commonwealth University, and his Ph.D. in Ecology from Old Dominion University. His dissertation focused on nitrogen fixation in termites, and has published several articles on termite biology in peer-reviewed scientific journals. For selected publications, please visit www.thetermitepage.com. In his current post as Biology Instructor at Radford University, he teaches Environmental Biology (BIOL 103). He serves as an AP Environmental Science reader with the College Board, and is an avid proponent of active learning using the Just-in-Time-Teaching (JiTT) method (www.jitt.org). He has presented online and active learning teaching methods at Bluefield State College, and presented these methods to interested faculty at Radford University, including learning catalytics, a web-based management solution for the interactive classroom (www.learningcatalytics.com). Dr. Curtis is Founder Cool School Review, (www.coolschoolreview.us), a Moodle-enabled web service for adjunct professors, K-12 teachers, tutors, and trainers to develop and deliver their course materials in an interactive classroom.

Appendix A
Percent to GPA Conversion Chart

Source: http://files.leagueathletics.com/Text/Documents/12742/41301.doc

Percent	GPA
0-59	0
60	0.7
61	0.8
62	0.8
63	0.9
64	1
65	1
66	1.1
67	1.2
68	1.3
69	1.4
70	1.5
71	1.6
72	1.7
73	1.8
74	1.9
75	2
76	2.1
77	2.2
78	2.3
79	2.4

Percent	GPA
80	2.5
81	2.7
82	2.8
83	2.9
84	3
85	3
86	3.1
87	3.2
88	3.3
89	3.4
90	3.5
91	3.5
92	3.6
93	3.7
94	3.8
95	3.9
96	3.9
97	4
98	4
99	4
100	4

Appendix B
Supplies

Carolina Biological Supply	item # 143736	100 termite workers	$40.95
Carolina Biological Supply	item # 173094	Drosophila sorting brush (12)	$8.50
Carolina Biological Supply	item # 143724	Termites Catch the Scent!	$24.25

Mission, Review Process & Disclaimer

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