Training and Mentoring TAs in Inquiry-Based Methods

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Abstract: The success of inquiry-based learning (IBL) in introductory laboratories is largely dependent on how well these labs are facilitated by teaching assistants (TAs). Since TAs generally have not experienced IBL and lack necessary skills to successfully use IBL in the classroom, training and modeling IBL for TAs is necessary. This paper details training methods used to overcome TAs misconceptions and fears about IBL and to build IBL facilitation skills. The methods include running TA lab meetings to boost IBL success, exposing TAs to IBL during a semester course, using planned questions to stimulate IBL, and using peer mentoring programs.

Introduction

Recent research indicates that effective science instruction includes students learning in an active manner and engaging in the scientific process; inquiry, therefore, is an important key to learning science. *Science for Americans* (Rutherford and Ahlgren, 1990), *Benchmarks for Science Literacy* (AAAS, 1993), and *National Science Education Standards* (NRC, 1996) stress the need for including IBL and investigative learning in teaching science at all levels. Inquiry-based learning (IBL) engages students, fosters critical thinking, builds problem-solving skills, improves attitude and achievement, and facilitates understanding (Dunn and DeBello, 1999; Tolman, 1999; Lord and Orkwiszewski, 2006). For these reasons, IBL is a critical component of undergraduate teaching laboratories and is an effective method for accomplishing instructional objectives in introductory biology labs. Increasingly, biology lab coordinators and curriculum developers are realizing the importance of presenting laboratory activities in an inquiry context and are delighted in the results these activities can have on students.

So, is IBL happening successfully in your biology labs? The answer to this question can greatly depend on who is "teaching" the lab. Facilitating IBL in a classroom is a skill that often requires "seeing" it before doing it, practicing it, believing in its effectiveness, having selfconfidence in teaching abilities, and thoroughly understanding the material. Successful inquiry-based facilitating also requires eliminating fears such as losing control of the class, overcoming misconceptions about learning, and letting go of more traditional forms of teaching. This is not an easy task and can be especially challenging for graduate and undergraduate lab teaching assistants (TAs). When attempting to facilitate IBL with their class, TAs run into difficulties and can easily become discouraged, especially if they do not have the skills or confidence necessary to teach IBL. How can TA developers tailor TA training to more effectively provide TAs with the confidence and skills to become facilitators rather than lecturers in the lab?

The presenters of this workshop have found that the answer to this question lies in exposing TAs to IBL before they teach *and* while they teach. This exposure occurs through the typical programs used by universities to train their science TAs, for example: general campus orientation, departmental orientation, course specific orientation, and/or continual education training throughout the semester. In order to enhance their IBL skills, effective preparation of teaching assistants for their first, or for their fourth year of teaching, requires a multi-faceted approach, encompassing some or all of these training programs. Some of the most successful methods used by the presenters are detailed in this paper.

TA Experiences, Misconceptions, and Fears about IBL

To better understand the IBL experience level of TAs and their misconceptions and fears about IBL, two surveys were given at the three universities (note: not all three universities gave out both surveys). One of the surveys is a modification of one used to assess graduate fellows at the University of Arkansas (http://gk12.uark.edu/programresults/GK12%20summer%20Pretest%20GradStdt2.pdf), and the other survey is a modification of an inquiry-based instruction assessment used by Linda Tompkins (Cornell University) at the National Association of Biology Teachers Conference in 2004. The surveys asked the TAs what their experience level was with various classroom activities (some being more traditional (e.g. receiving factual information from a lecturer) and some being more inquiry-based (e.g. think critically to make relationships between evidence and explanations)), what their confidence level is with these activities, how important they thought these activities were in an IBL lab, and how often they used these activities when they taught lab investigations.

Not surprisingly, only 5% of the TAs had any experience with IBL activities in the past and only 10% have been involved in an active learning activity as a student. Misconceptions included believing students need to listen to lectures to learn facts, assuming IBL is more difficult to manage, assuming IBL is not effective for student learning, and assuming that other science students learn the same way the TAs do. Interestingly, even with their lack of experience and plethora of misconceptions, TAs had a good sense about which activities were most important when using IBL in a classroom. However, they also indicated that lecturing, memorizing concepts, and directing investigations (cookbook labs) were moderately important in an IBL lab.

TAs that had been exposed to IBL either via recent training by the lab coordinator or by having taught an IBL lab had more confidence in using IBL techniques while teaching than the TAs who had been minimally (or not at all) exposed to IBL. Furthermore, even though many of the IBL techniques were rated as important when teaching IBL labs, many TAs admitted to using these techniques less so when they were teaching and depending more heavily on traditional, didactic methods. This is actually not a new phenomenon: many research studies have shown that teachers who have little to no experience with IBL often revert to the traditional way they have been taught because they know "that way" all too well (Hammrich, 2001; Luft *et al.*, 2004). TAs are more comfortable with this traditional, didactic teaching style since it gives them a sense of control, which is greatly desired by those TAs who lack teaching experience, have fears about student-centered instruction, and, in many cases, lack deep understanding of the content material. Giving the "ball" to their students during lab, whether that be letting the students ask their own questions and design their own investigations (open inquiry) or just letting them design a way to collect the data and make their own conclusions (directed inquiry), requires an uncomfortable and unfamiliar level of critical thinking and teaching skills for the TAs. As revealed by the surveys, it takes seeing IBL in action before believing in IBL, it takes believing in it before practicing it, it takes practicing it to be comfortable with it, and it takes a lot of comfort and experience to facilitate it successfully. Hence the need to incorporate exposure to and practice with IBL during many of the TA training programs implemented at a university.

Although TA training is necessary to develop confidence and skills, a TA developer must also work to change the attitude and beliefs of the TAs about IBL. Misconceptions about IBL, fear of losing control, and initial dissatisfaction with the amount of time IBL can take oftentimes result in TAs being resistant to using IBL methods, thus creating a roadblock for the success of IBL labs. The presenters refer to this resistance and associated negative attitude as lack of TA *buy-in*. As many colleagues have noticed, *buy-in* by TAs on IBL methods does not automatically co-occur with beginning to use IBL methods in the teaching labs. Initially, TAs can be very critical of the IBL approach mostly because of the loss of control issues mentioned above. Furthermore, when you first introduce IBL into the teaching labs, there are very few people who can effectively model it for the TAs. By implementing various facets of IBL throughout the various training programs, the TAs become more receptive, positive, and confident in teaching by inquiry, as indicated by our initial survey results. TAs who do *buy-in* to the IBL approach become mentors, influencing the *buy-in* of new TAs and encouraging the success of the IBL approach in the classroom.

Background

The presenters of this workshop coordinate multi-section, introductory biology laboratories for science majors (Table 1). These labs are taught by TAs with a myriad of background experiences. All three presenters have introduced IBL to their introductory biology labs, but the level of IBL in the labs differ in two ways: 1) the extent to which the lab is either guided or more open ended (NAP, 2000; Rezba et al, 1999), and 2) the number of IBL investigations that occur throughout a course.

Each of the three university programs presented in this paper use a multi-faceted approach for training TAs for teaching biology laboratories (Table 2). Training TAs on IBL methods is integrated into these program components in a myriad of ways, as detailed below.

Table 1. Profile of introductory biology labs at presenters' universities.

	University of Kentucky	University of Dayton	University of North Carolina at Chapel Hill
# students/semester	~600	~400	~800
#sections taught	18 (35 students per section)	~20 (20 students per section)	~ 30 (25 students per section)
# TAs assigned to intro labs	18 (two TAs per section)	10 (1 TA per section)	15 (1 TA per section)
TA diversity	International and Domestic	Primarily Domestic, becoming more mixed	Primarily Domestic
IBL introduced to the intro labs	1 year ago	2-3 years ago	4 years ago
# IBL lab exercises	Several	Several	Most

Table 2. TA Training Profile at Presenters' Universities.

	University of Kentucky	University of Dayton	University of North Carolina at Chapel Hill
Pre-semester Orientation	2 days	3-4 days	2 days
Weekly Lab Meetings	2 hours per week	2 hours per week	2 hours per week
College Teaching Seminar Course	N/A	Yes	N/A
Mentoring Program (how long in place?)	1 year – IBL specific	Just for ITAs	10 years; multi-tiered
IBL Buy-in by TAs	nascent	evolving	developing

Methods for Training TAs on IBL

University of North Carolina at Chapel Hill

TA training at the University of North Carolina at Chapel Hill includes increasing awareness of and enhancing skills with IBL through a two day TA orientation at the beginning of the semester, weekly TA preparatory meetings and TA mentoring. These programs include the following components:

Pre-semester Orientation:

- New TA Training - University policies, Grading policies, Resources for TAs, Advice from experienced TAs, Course objectives (IBL included in discussion of some lab activities and in writing sample test questions).
- All TA Training - General course policies

Weekly Prep Meeting:

Head TA teaches a lab each week to the new TAs. The Head TA "models" the role of a TA and shows how TAs should guide their students through the lab activity. Template slides are used and are available to all TAs via Blackboard. Sample IBL questions that TAs can use in their brief lectures are also accessible (contact Barbara Stegenga for a sampling of these questions).

Mentoring Program:

TAs who have previously taught the lab are able to mentor if there are enough undergraduate TAs to teach labs. The number of mentors depends on the number of undergraduates teaching each semester. Mentors rotate among labs each week and offer advice and critique the new TA. Mentors schedule meetings with the TAs to go over a written commentary. New TAs are also videotaped as part of the training process.

University of Dayton

At the University of Dayton objectives for TA training are to increase awareness of and enhance skills with IBL through a pre-semester TA orientation at the beginning of the semester, weekly TA lab meetings, and a College Teaching Seminar. These programs include the following components:

Pre-semester Orientation:

- New TAs are introduced to the article, "Seven principles for good practice in undergraduate education" (Chickering and Gamson, 1987) during the university GTA orientation.
- New TAs further the discussion on this article during the discipline-specific orientation. TAs also discuss how to effectively facilitate student investigations and other basic effective pedagogical techniques (being attentive, encouraging critical thinking, etc).
- TAs practice their pre-lab presentations for the first lab which is a guided inquiry lab (scientific process lab using termites as the model organism). All new TAs watch each other and give constructive criticism to each other regarding these presentations.

Weekly TA Lab Meetings (course specific):

- All TA's attend the first part of these meetings, which details administrative information, preparatory information, and discussion between new and returning TAs about important things to consider and remember for the week.
- Any TA who has not previously taught that week's lab stays at the meeting to run through the investigation for the week.
- Either an experienced TA or the lab coordinator will model how to present the lab (IBL methods when used).
- Many experienced TAs stay for the remainder of the meeting to review and to help the new TAs with techniques, learning equipment, and tips for dealing with student problems.

College Teaching Seminar (semester long course taken by all new TAs):

- The goals of this course include, among other things, enhancing basic pedagogical skills of TAs, introducing TAs to learning theories (including constructivism and IBL);

practicing effective teaching techniques (including IBL); helping TAs to become reflective practitioners; and training TAs on authentic assessment techniques.

- Before IBL is introduced, students read and discuss journal articles and/or book chapters about constructivism, pedagogical content knowledge, student centered learning, and learning styles. Each semester, TAs are encouraged to find these articles to read (search in the following journals: American Biology Teacher, Journal of Science Teacher Education, Journal of Research in Science Teaching, Journal of Biology Education, Bioscience, and Journal of College Science Teaching).
- Before discussing IBL, TAs have taught both an inquiry based lab (the first lab on the scientific process) and a relatively traditional (cookbook) lab on biological instrumentation.
- IBL is introduced by using the 5E learning cycle (Appendix A), which was originally conceived by Roger Bybee at BSCS. This format is used for structuring the IBL lesson since the TAs will later be expected to use the 5E learning cycle to convert a cookbook investigation into an inquiry-based investigation.
    - Students are asked, "what is inquiry?"
    - Students then read separate short articles/excerpts on inquiry-based learning, share what they read, and collaborate to describe how IBL differs from a more traditional, didactic approach.
    - Students are asked to discuss ways that a traditional lab could be altered into a more inquiry-based lab.
    - Instructor discusses the continuum between closed inquiry and open inquiry based on the examples that the TAs present (NAP, 2000; Rezba et al, 1999).
    - TAs are introduced to the 5E learning cycle as a way to facilitate and plan inquiry-based learning lessons.
    - TAs convert a cookbook lab investigation into an inquiry-based one using the 5E learning cycle.

University of Kentucky

TA training at the University of Kentucky is similar to the University of Dayton with regards to pre-semester orientation and the weekly lab meeting format. They differ with respect to continuing education of TAs on the IBL approach. At the University of Kentucky a mentor/mentee program is utilized to reinforce best teaching practices, as well as foster the IBL approach.

*Pre-semester Orientation (*Appendix A*):*

- New TAs - Pedagogy, Inquiry Based Lab Instruction, Assessments, etc. General Policies.
- All TA orientation- New policies and program changes presented to all TAs.

Weekly Lab Meeting:

Experienced TAs selects a topic they would prefer to develop into IBL (lab coordinator assists with the development of these labs). Then, this TA leads the IBL training of peers during the TA lab meeting (note: timing during semester and duration of training are key).

Mentoring Program: (Varies depending upon the needs of the TAs each semester)

This has been implemented in two ways:

1. A specific mentor (i.e., an independent experienced TA) selects up to four inexperienced TAs with whom they will meet to discuss the upcoming laboratory and best teaching

strategies and practices. This is accomplished through either one on one interaction or through a group mentor/mentee meeting, depending on the needs of the newer TAs. In addition, the lab coordinator meets with all the mentors once a week to coordinate the upcoming information, in order to relay and to discuss mentoring related issues.

2. Alternatively, mentor/mentee relationships are established through the weekly TA lab meetings, by establishing work groups of no more than four TAs per group. The group will be comprised of at least one experienced TA who will function as a mentor to the other members in their group during the TA lab meeting (i.e modeling the IBL approach in the smaller groups).

Special Note:

1. We are in the process of revising the IBL surveys mentioned above and developing other surveys to administer to both TAs and their students to assess their impression of the IBL approach in teaching labs, as well as assessing the effects on learning outcomes. If you are interested in using these surveys, have surveys you would like to share with others, or would like to help develop these surveys, please contact the authors.
2. Please see Appendix C for a list of resources on TA training, using IBL in labs, converting traditional labs to inquiry labs, and using the 5E learning cycle.
3. Please see Appendix D for a comment list about other TA training techniques from our workshop participants.

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National Academy Press. 2000. Table 2-6. Essential features of classroom inquiry. In Inquiry and the National Science Education Standards. P. 29

National Research Council. 1996. National Science Education Standards. Washington, DC: National Academy Press.

Rezba, R. J., T. Auldridge, and L. Rhea. 1999. Teaching and learning the basic science skills. Available online at www.pen.k12.va.us/VDOE/instruction/TLBSSGuide.doc

Rutherford, F.J. and A. Ahlgren. 1990. Science for All Americans. New York: Oxford University Press.

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About the Authors

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Alma Ferrier received her B.S. in Biology from the St. Mary's College, Notre Dame, Indiana and her Ph.D. in Molecular and Cellular Biology from the University of Kentucky. She is currently the Academic Coordinator for Introductory Laboratory Courses for Life Science Majors at the University of Kentucky. She is involved in curriculum development for the introductory lab courses and coordinates the Biology teaching assistant orientation and training programs.

Appendix A: 5E Learning Cylce

The 5E learning cycle, conceived by Roger Bybee at BSCS, is a great tool to use to plan IBL lessons and to train TAs on creating IBL experiences for their students. It consists of the 5 phases detailed below. Although the 5 phases are usually presented in the order below, it is not necessary to abide by this order, and, in fact, many practitioners will jump back and forth between two or three phases of the cycle before completing a lesson. It is important to stress that the last E listed below, evaluation, is not actually a separate phase of the cycle; instead, it is something that should occur during each of the other phases of the cycle. For further information about this cycle, where it originated from, how it has been used by other practitioners, etc., please see Appendix C.

Engage: This phase of the cycle is intended for engaging your students in the topic of the lesson. It should peak their curiosity and excite them. Usually, this means finding a way to make the topic relevant to their lives. The engage activity can be a demonstration, a picture, a joke, a problem, a video, etc. To lead to good scientific inquiries in the next phase, the engage activity should lead the students to ask good scientific questions that could be answered by an investigation in the explore phase.

In addition to engaging your students, the engage activity should also solicit your students preconceived notions about the topic. By soliciting their preconceived notions, you can assess if they have misconceptions about the topic and what these misconceptions are. With this information revealed, you can structure the rest of the sequence accordingly so as to overcome your students' misconceptions.

Explore: This phase of the cycle is where the students get to explore the topic on their own (or in a group of peers). They could explore by watching a video, reading a book, reading a journal article, constructing a model, completing an investigation based on a question they ask, making observations, etc. The teacher can facilitate this phase by asking good, high level, guiding questions.

Explain: To be inquiry-based, this phase should always come AFTER the explore phase, not before! Here, students explain their results from an investigation (or from another type of explore activity) and provide conclusions based on evidence. The students explain the concept, the problem, and/or the results and offer alternative explanations. The "teacher" can introduce new terminology here as the concepts come up in the students' explanations. Discussion between students is highly encouraged.

Extend/Elaborate: During this stage, the students extend their new knowledge to a new investigation, problem, topic, etc. Or, they elaborate on the concept at hand. This stage can be used to encourage the students to probe further into the topic and to see if they can apply their new knowledge to new examples and/or real world problems. Perhaps the explore investigation gave unexpected results or brought up a new question – here is the part of the learning cycle where the students would design and run another experiment to answer their new question or attempt to explain their unexpected results.

Evaluate: Use many different authentic assessment techniques to evaluate student learning throughout.

Appendix B: Sample of Departmental and Course Specific Orientation Program for Biology TAs at the University of Kentucky

SEGMENT 1 **New TAs**

General Teaching Information and Strategies:

"VARK- A Guide to Learning Styles"
- http://www.active-learning-site.com/
- http://www.vark-learn.com/english/index.asp

Bloom's Taxonomy
- http://www.mscd.edu/~options/online/principles.html

Good Teaching Practices-
- http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/7princip.htm
- http://www2.msstate.edu/~dsm5/table.html

Tools for teaching-
- http://teaching.berkeley.edu/compendium/

Teaching Goals Inventory On-line-
- http://www.uiowa.edu/~centeach/tgi/book.html

SEGMENT 2 **New TAs**

Inquiry Based Learning:
- 5 E's of Learning-http://enhancinged.wgbh.org/research/eeeee.html

Assessment as a learning tool

Classroom Assessment Techniques- *Formative and Summative Evaluation*
- http://www.iub.edu/~teaching/feedback.shtml

Some examples of Classroom Assessment Techniques
- http://www.mines.edu/Academic/affairs/circuit/asho.html

SEGMENT 3 **ALL** TAs
- Introductions
- Training on *New* inquiry based laboratory measuring hand grip strength using Vernier technology. (All TAs were learning a new inquiry based lab together)
- Fetal Pig Dissections (Returning TAs function as Mentors for New TAs)

SEGMENT 4 **New** TAs
- Microscopy training
- Fetal Pig dissection continued
- Inquiry Based lab training on Scientific Method (Termite Lab) New Lab to this course. (New TAs learn first and will be mentor to returning TAs) New TAs revised the lab and became the presenters of this lab to the returning TAs in the next segment.

SEGMENT 5 **ALL** TAs
- New TAs presented in an inquiry manner the lab on which they were trained in segment 4 to the returning TAs.
- Respiration Lab training using Vernier equipment. Returning TAs are mentoring the New TAs.

Appendix C: Resources

TA training:

Davis, W., J. Smith, and R. Smith (Eds). 2002. Ready to Teach: Graduate Teaching Assistants Prepare for Today and for Tomorrow. New Forums Press, Inc., Stillwater, OK.

The Journal of Graduate Teaching Assistant Development. New Forums Press, Inc., Stillwater, OK.

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Tomorrow's Professor Mailing List. Stanford Center for Teaching and Learning. http://ctl.stanford.edu/Tomprof/index.shtml

Using IBL in science teaching laboratories:

Anderson, R. D. 2002. Reforming science teaching: What research says about inquiry. Journal of Science Teacher Education, 13(1): 1-12.

Guided inquiry through case studies:http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm

- Enables the TA to facilitate rather than lecture.

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Converting Traditional Labs to Inquiry Based Labs:

Bernstein, J. 2003. A recipe for inquiry: A traditional cookbook lab for determining the molar volume of a gas is modified to include inquiry. The Science Teacher, 70(6): 60-63.

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Uncooking the Lab: How to convert a traditional "cookbook" lab into an inquiry-based lab. The Wisconsin Program for Scientific Teaching. http://scientificteaching.wisc.edu

Volkmann, M. J. and S. K. Abell. 2003. Rethinking laboratories: Tools for converting cookbook labs Into inquiry. The Science Teacher, 70(6), 38-41.

Using the 5E learning cycle:

Eisenkraft, A. 2003. Expanding the 5E model: A proposed 7E model emphasizes "transfer of learning" and the importance of eliciting prior understanding. The Science Teacher, 70(6): 56-59.

Trowbridge, L. W., R. W. Bybee, J. Carlson-Powell. 2003. Teaching Secondary School Science: Strategies for Developing Science Literacy. 8th ed. Prentice Hall.

The Biological Sciences Curriculum Study (BSCS) homepage. http://www.bscs.org/

- Roger Bybee first conceived the 5E Learning Cycle at BSCS.

Also – type in 5E learning cycle in Google and you will find hundreds of websites.

Appendix D: Comments from Participants on Methods They Use to Train and Mentor TAs in IBL

- TAs go through the exercise just as students are expected to do it. Answers are not given, but they work in groups to get a hypothesis and come up with a method for doing the experiment.

- A two to three day training session dealing with student management and teaching techniques is held. Case studies and skits are completed to demonstrate points.

- Bring up scenarios and common questions during prep meetings that students and/or TAs have had with particular inquiry labs. Discuss how to deal with these.

- TAs do the "dry run" of the labs and attend a 2 day workshop to discuss IBL techniques.

- TAs read paper about TA responses to IB labs, which deals with both common problems and solutions, but also provides stats on why the TAs come to prefer teaching IBL. Ex: Teaching IBL helps the TAs improve experimental design skills.

- During weekly TA meeting the lab is "taught" and then we act as a model for the techniques the TAs can use.

- Have TAs give a 10 minute "practice" lab demo in front of other TAs and instructors on a topic of their choice. The other TAs and instructors then give each TA feedback on their performance.

- During weekly TA meetings we go through a whole lab before it is taught to the students. TAs see lab from students perspective.