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Time-Restricted Inquiry-Based Learning Promotes Active Student Engagement in Undergraduate Zoology Laboratory †

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Organizing a zoology laboratory for an undergraduate course is often a challenge, particularly in a limited-resource setting, due to the vast variety of topics to cover and the limited numbers of preserved specimens and permanent slides. In zoology, the class structure generally takes the form of a lecture demonstration followed by sample exhibition stations. This setting often fails to actively engage the majority of students in exploring the specimens. Here we propose an alternative organization of a zoology class lab format comprised of short guided-inquiry, time-restricted lab stations, and a freely structured follow-up project intended to increase attention and conceptual understanding of the lab topic. The lab is designed in two parts: a 10-minute in-class rotation portion, where small groups of students take turns investigating specimens following an instructor demonstration, and an after-class group assignment. We implemented the strategy for two years, and it is clear that our approach significantly increased students' active engagement in the class. The time-restricted scheme ensures all students participate despite limited resources, while the guided instructions keep the students focused on the topic. Furthermore, the team assignment portion, in particular the media creation aspect, promoted teamwork among group members.

การจัดประสบการณ์การเรียนรู้ในวิชาปฏิบัติการสัตววิทยาสำหรับนักศึกษาในหลักสูตรระดับปริญญาตรีนั้นมักจะเป็นสิ่งที่ท้าทาย ทั้งนี้ เนื่องจากทรัพยากรที่จำกัดทั้งในด้านตัวอย่างและสไลด์ถาวร ด้วยเหตุนี้ การเรียนในห้องปฏิบัติการสัตววิทยาจึงมักถูกจัดในรูปแบบของการสาธิตและการจัดแสดงนิทรรศการเป็นฐานกิจกรรมย่อย แม้ว่าการจัดประสบการณ์การเรียนรู้แบบนี้อาจจะใช้ได้ดีกับนักเรียนที่มีผลสัมฤทธิ์สูงที่มีความสนใจในการศึกษาตัวอย่างและนิทรรศการที่จัดไว้ด้วยตนเอง แต่มักจะไม่สามารถกระตุ้นให้นักเรียนส่วนใหญ่สนใจศึกษาตัวอย่างได้ ในการนี้ ผู้วิจัยได้เสนอแนวทางในการจัดประสบการณ์การเรียนรู้ในวิชาปฏิบัติการสัตววิทยาแบบใหม่ซึ่งอาศัยการจัดกิจกรรมเพื่อการสืบเสาะหาความรู้แบบชี้แนะแนวทาง (guided inquiry) แบบสั้นๆ เพื่อเพิ่มความสนใจนักศึกษาในชั้นเรียน การจัดปฏิบัติการในแต่ละฐานนั้นจะมุ่งเน้นเพื่อพัฒนากรอบแนวคิดในหัวข้อเฉพาะ การจัดปฏิบัติการในงานวิจัยนี้ถูกออกแบบให้มี 2 ส่วนหลัก ส่วนแรกคือกิจกรรมในห้องเรียน ซึ่งแบ่งเป็นกิจกรรมในฐานต่างๆ (rotation station) โดยแต่ละกิจกรรม นักเรียนกลุ่มเล็ก ๆ จะเวียนกันทำกิจกรรมในสถานีย่อยตามการชี้นำในเอกสารประกอบ เป็นเวลาฐานละ 10 นาที และกิจกรรมกลุ่มนอกเวลาเพื่อทำงานตามที่ได้รับมอบหมายให้สำเร็จ หลังจากทดลองประยุกต์ใช้กลยุทธ์ในการจัดปฏิบัติการเช่นนี้เป็นเวลา 2 ปี พบว่ากลวิธีนี้สามารถเพิ่มการมีส่วนร่วมของนักเรียนในชั้นเรียนได้อย่างเห็นได้ชัด การให้เวลาที่จำกัดจะช่วยกระตุ้นให้นักศึกษาเร่งรัดและใส่ใจที่จะทำการทดลองแม้จะมีทรัพยากรที่จำกัด ส่วนคำแนะนำในการทำกิจกรรมตามเอกสารประกอบนั้นจะช่วยให้นักศึกษาสามารถทำงานไปตามหัวข้อที่กำหนดได้ นอกจากนี้ยังพบว่าการมอบหมายงานกลุ่มนั้นยังช่วยให้ทุกคนมีส่วนร่วมในงานของกลุ่ม โดยเฉพาะอย่างยิ่ง การสร้างสื่อแบบต่างๆ ยังมีส่วนช่วยในการส่งเสริมการทำงานเป็นหมู่คณะของสมาชิกภายในกลุ่มอีกด้วย

INTRODUCTION

Zoology courses cover a broad range of topics, including knowledge of animal taxonomy, life cycle, biodiversity, and the role of evolution in shaping the form and function of different animals. As a result, zoology courses must incorporate large numbers of specimens to introduce students to different types of animals at various points of

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their life cycle. However, some regions, including Thailand, have limited resources and access to only limited numbers of preserved specimens, permanent slides, and microscopes. Undergraduate zoology laboratory courses in Thailand are often arranged as a lecture with exhibition stations to cope with the lack of available learning materials.

In this traditional setting, student instructions are often provided in the form of a laboratory manual and a laboratory briefing prior to starting the lab class. After a short briefing, students are expected to explore the different stations and complete a lab assignment worksheet, on which they report individually. Frequently, other activities, such as a lab quiz, are implemented at the end of class to motivate students to rigorously explore all the stations. Although this setting has been widely used in the classroom for decades, it often fails to engage the majority of students. It was found that despite the rigorous prelaboratory briefing, students still lacked conceptual and procedural understanding of the topic (1, 2). Some students were able to develop a conceptual understanding of how biodiversity, evolution, and taxonomic classification are interconnected, but this understanding was largely dependent on the quality of class teaching assistants (TAs) and instructors (2). These higher-achieving students often gathered around stations where the TA was present and active, while other students were at other stations working on their own. Often, students relied on images of a specimen captured using a phone or tablet to complete drawing or sketching assignments rather than studying the actual specimen at the station. Sometimes, they used images from the Internet. This negated the purpose of the zoological lab class, reducing students' conceptual understanding of the course material. Moreover, students also struggled in labs with complex experiments, becoming mired in procedural details about the experiment rather than developing a conceptual understanding of the subject being studied. Finally, when a group project was assigned, a few members of the team tended to complete the report while the rest of the team remained unengaged in the course content and lab activities.

To address this lack of engagement, we added an inquiry-based aspect to the lab class. It has been widely shown that an inquiry-based strategy can help improve student engagement and increase student performance in different classroom settings (3–7). The guided inquiry process allows students to develop their own ideas from different sources of information, with only a simple guided instruction from the lab instructor or TA. After each individual develops an understanding of the topic, ideas and resources are shared and developed among peers in small groups to promote student engagement in the activity (8–10). Finally, groups present their results in various creative ways, such as small science projects or group presentations (8–10). Despite some advocacy from the government, the implementation of inquiry-based learning in science education in Thailand is still largely limited, even in schools and institutions where resources are abundant (11). Most inquiry-based approaches implemented in schools in Thailand are structure-based (11). Guided and open inquiries are sometime arranged for senior undergraduate students in large universities or for gifted students in well-funded schools. One of the major concerns in incorporating inquiry-based learning in the classroom is the lack of supporting facilities (12). Moreover, this type of learning often takes longer to implement. Our approach was developed to help maximize the use of limited resources to increase student engagement using task-based

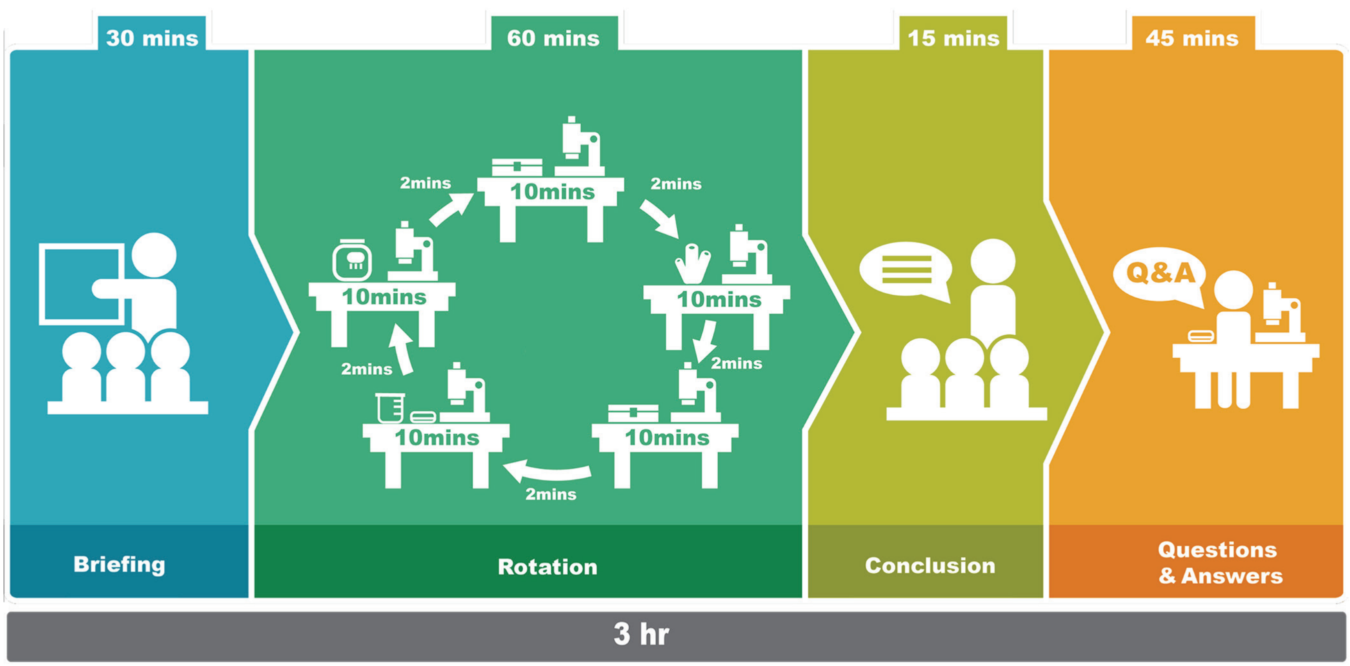

FIGURE 1. Strategic time management for the in-class activities.

assignments and a time-restricted guided-inquiry learning protocol. The tasks were designed to incorporate different levels of inquiry-based learning from structured to guided to simple open inquiries. From our observations, the time restriction significantly helps encourage students to focus their attention on specimens and class materials and participate in the team effort. Our approach appears to not only help actively engage students with the lab activities but also promote peer-to-peer communication and team work. With some modifications, our laboratory design can be beneficial to similarly sample-limited regions in which zoological courses are taught.

PROCEDURE

The strategy was implemented in an undergraduate zoology class of 50 students. Students were in their sophomore year, ranging from 18 to 20 years old. Each lab class correlated with a preceding instructor lecture in corresponding topics. Students were divided into 10 groups of five students. Five lab stations were set up to accommodate two groups (10 students) at each station. A guided inquiry–based laboratory assignment was designed to require both in-class activities and after-class activities. Both parts of the assignment were completed in groups based on the notion that cooperative learning helps increase the learning performance of students (13, 14). Students worked collaboratively to collect data and complete the in-class activity, and the group discussed and developed a presentation idea during the after-class activity. Often, the presentation incorporated media such as movies and infographics. Group assignments were due within two weeks of the lab class.

In-class activities: Time-restricted lab rotation

The guided inquiry–based practical task is designed based on the key conceptual idea for each topic and includes a variety of activities to ensure the task is both interesting and challenging for students (15). The guided instruction for in-class activities was planned to train both cognitive and psychomotor skills. As the average attention span of students has been reported to be around 10 to 15 minutes, all the tasks for in-class activities were designed to be completed within 10 minutes (16). In each task, students were allowed to collect data using provided specimens at the station table. An alarm signal was used to remind students to move to the next station, forcing students in the group to participate in activities at each station and encouraging active contribution among the team members. To foster respect for others and for the materials, students used two minutes after the alarm signal to clean up and reset their current station before rotating to the next station. A question-and-answer session at the end of class enabled students to discuss, collect more data, and implement critical thinking on the more challenging aspects of the task. Sample lab stations are shown in Appendix 1.

After-class assignment: Collaborative learning

To foster a group active-learning experience, after-class assignments challenged the students to scrutinize the problem and find a way to effectively communicate their ideas to their peers (8, 14). The in-class team activities were designed to be different at every station, ranging from drawing to comparing animal structures and forms to capturing images for their assignments and answering questions related to the topics. The after-class assignments combined the in-class stations with student creativity. Free tools such as "Facebook live" and "Piktochart" (17) were used to make movies or infographics to be published online. The format of the presentation was left open so individual groups could decide how to present the assignment. Impressively, the students in the study produced high-quality movies presented in different styles, including conventional voice-narrated shows, animation, and stop motion. Samples of these movies are available upon request.

CONCLUSION

After two years of implementation, our lab strategy has been found to promote active student engagement in zoology classes. Students not only learned about the topic, but were also able to organize themselves to work as a team. We found that students successfully collaborated and distributed tasks among themselves within minutes during the in-class time-restricted challenge. The time-restriction was essential to encourage contribution from all team members. Diverse tasks, such as drawing, experiments, and collecting data for presentations, were used during the in-class assignments to accommodate the attention span of the students. Students quickly leveraged online social tools, including Facebook groups, Line, Google Drive, and Dropbox, to share resources among the team to complete the after-class project. The collaborative nature of the assignments helped promote team-building skills within the groups of students. Our approach clearly demonstrated that the time-restricted guided inquiry could be effectively implemented in undergraduate zoology laboratory classes to actively engage students in class activities.

SUPPLEMENTAL MATERIALS

Appendix 1: Lab instruction for class about sponges and *Cnidaria* (for TAs & instructors)

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REFERENCES

1. Rollnick M, Zwane S, Staskun M, Lotz S, Green G. 2001. Improving pre-laboratory preparation of first year university chemistry students. Int J Sci Educ 23(10):1053–1071.
2. Pogacnik L, Cigic B. 2006. How to motivate students to study before they enter the lab. J Chem Educ 83(7):1094–1098.
3. Adams DJ. 2015. Current trends in laboratory class teaching in university bioscience programmes. Bioscience Educ 13(1):1–14.
4. Burrowes PA. 2007. How to make a field trip a hands-on investigative laboratory: learning about marine invertebrates. Am Biol Teach 69(4):54–58.
5. Martineau C, Traphagen S, Sparkes TC. 2013. A guided inquiry methodology to achieve authentic science in a large undergraduate biology course. J Biol Educ 47(4):240–245.
6. Timmerman BE, Strickland DC, Carstensen SM. 2008. Curricular reform and inquiry teaching in biology: where are our efforts most fruitfully invested? Integr Comp Biol 48(2):226–240.
7. Kuhlthau CC, Maniotes LK, Caspari AK. 2007. Guided inquiry: learning in the 21st century. Libraries Unlimited, Santa Barbara, CA.
8. Tornee N, Bunterm T, Tang KN. 2017. The impacts of inquiry-based learning model on teaching science subject: a case study in Thailand. Turk Online J Educ Tech Spec Iss INTE 395–402.
9. Kuhlthau CC, Maniotes LK, Caspari AK. 2012. *Guided inquiry design: a framework for inquiry in your school.* Libraries Unlimited, Santa Barbara, CA.
10. Bonwell C, Eison J. 1991. Active learning: creating excitement in the classroom. AEHE-ERIC Higher Education Report No. 1. Jossey-Bass, Washington, DC.
11. Bunterm T, Lee K, Ng Lan Kong J, Srikoon S, Vangpoomyai P, Rattanavongsa J, Rachahoon G. 2014. Do different levels of inquiry lead to different learning outcomes? A comparison between guided and structured inquiry. Int J Sci Educ 36(12):1937–1959.
12. Zion M, Mendelovici R. 2012. Moving from structured to open inquiry: challenges and limits. Sci Educ Int 23(4):383–399.
13. Eberlein T, Kampmeier J, Minderhout V, Eberlein T, Kampmeier J, Minderhout V, Moog RS, Platt T, Varma-Nelson P, White HB. 2008. Pedagogies of engagement in science: a comparison of PBL, POGIL, and PLTL. Biochem Mol Biol Educ 36(4):262–273.
14. Bowen CW. 2000. A quantitative literature review of cooperative learning effects on high school and college chemistry achievement. J Chem Educ 77:116.
15. Bruck LB, Towns MH. 2009. Preparing students to benefit from inquiry-based activities in the chemistry laboratory: guidelines and suggestions. J Chem Educ 86(7):820–822.
16. Wilson K, Korn JH. 2007. Attention during lectures: beyond ten minutes. Teach Psychol 34:85–89.
17. Bellei M, Welch P, Pryor S, Ketheesan N. 2016. A cost-effective approach to producing animated infographics for immunology teaching. J Microbiol Biol Educ 17(3):477–479.