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Using Problem-Based Learning (PBL) to Teach Geographic Information Science

Heather Peacock

The University of Western Ontario, hpeacock@uwo.ca

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ABSTRACT

Geographic Information Science (GIScience) is a field of study that investigates the development and use of theories, methods, technology, and data for understanding geographic processes, relationships, and patterns (Mark, 2003). Students in the discipline learn the conceptual and technical implementation of Geographic Information Systems (GIS; the analysis, storage, visualization, and management of geographic data). However, GIScience undergraduates often struggle to relate GIS theory to technical practice. In particular, students have difficulty mastering GIS tools and software and they are not well-equipped to determine the series of processes/tools required to complete geoprocessing tasks without prompts. GIScience courses commonly provide students with detailed step-by-step instructions on how to execute various GIS tools in order to solve example problems but students are eventually expected to perform the same or similar problem-solving tasks without detailed instructions.

This workshop focuses on how to teach the technical and problem-solving skills required in GIScience courses effectively by employing a problem-based learning (PBL) model. PBL is an active learning method that increases understanding and competency. The approach focuses on problem solving, self-directed learning, team participation and cooperation (Pawson et al., 2006). PBL encourages students to use critical thinking, engages their curiosity to solve real-world problems, and promotes inquiry and interest in the subject matter (Pawson et al., 2006). A PBL approach encourages students to collaboratively solve problems in GIScience by first identifying the general steps to solve the problem and then solve those problems by determining the tools needed to process the data to come to a solution (Melero, 2010). Incorporating PBL into GIScience courses enables students to solve a larger variety of problems, promotes stronger retention of skills and theory, and better prepares them for future professional opportunities and/or academic research.

KEYWORDS

Geographic Information Science (GIScience); problem-based learning (PBL); active learning in geography

LEARNING OUTCOMES

By the end of this workshop, participants will be able to:

- Model and teach students effective GIScience problem-solving skills following a problem-based learning (PBL) approach.
- Develop hands-on exercises that reinforce disciplinary theory and encourage students to solve problems in GIScience collaboratively.

ANNOTATED BIBLIOGRAPHY

Drennon, C. (2005). Teaching geographic information systems in a problem-based learning environment. *Journal of Geography in Higher Education*, 29(3), 385-402.
<https://dx.doi.org/10.1080/03098260500290934>

Drennon cites Margetson (1999) who suggests that PBL provides a revised, problem-focused curriculum that recognizes “medical problems are constitutive of medical practices” and “therefore the typical student’s understanding, knowledge, and skill are interrelated, forming a whole which develops in response to problems” (p. 363). While Margetson uses medicine as an example, the approach is easily transferred to GIScience. Drennon outlines the value of PBL as a pedagogy that supports the development of new skills through self-direction, and addresses its use in teaching GIScience courses.

Drennon also summarizes Boud and Feletti’s (1991) four stages of problem-based instruction and learning:

1. Students work in groups to define the nature of an authentic problem while relying on their shared knowledge/ideas.
2. Students articulate questions, including aspects of the problem they do not understand (i.e., define what they know and what they do not know).
3. Students rank the questions/issues, define the resources necessary to achieve better understanding, and divide the labour among themselves to pursue answers.
4. Students present and summarize their findings and decide on how to proceed as a group.

The article goes on to describe an experimental class in which Drennon used PBL methods and a real-world example to teach GIScience to non-geographers. Instead of teaching the GIS theory and then applying it to an example, the case-study was presented first and GIS theory and technical skills were taught as students asked for the information they needed to know in order to solve the problem.

This article is used to inform the lecture section of the workshop and provide a tangible example of how PBL can be effective in teaching GIScience to new users. The group discussion activity aligns with the four-step process detailed above and provides a clear example of PBL methodology for participants.

Pawson, E., Fournier, E., Haigh, M., Muniz, O., Trafford, J., & Vajoczki, S. (2006). Problem-based learning in geography: Towards a critical assessment of its purposes, benefits and risks. *Journal of Geography in Higher Education*, 30(1), 103-116.
<https://dx.doi.org/10.1080/03098260500499709>

This paper defines PBL, outlines its benefits and challenges, provides multiple examples of its use with positive results, and identifies best practices. Pawson et al. critically assess the use of PBL to teaching geography and conclude that PBL is an effective approach but success is dependent on course preparation and design.

This source will be used to inform the lecture section of the workshop. Facilitators could consider sharing a handout summary of Table 1 from the article as take-home material for participants.

King, E. (2008). Can PBL-GIS work online? *Journal of Geography*, 107(2), 43-51.
<https://dx.doi.org/10.1080/00221340802202237>

The goal of the article is to evaluate the effectiveness of using PBL in online courses by comparing a PBL-based course to a non-PBL-based course. Results of the study suggest that focusing on personally relevant and interesting problems increases engagement and achievement of learning outcomes because it promotes deeper discussion and critical thinking (i.e., learning is enhanced when students focus on solving relatable problems). The article supports the use of online tools for teaching GIScience and the use of online formats for teaching adult learners. Course evaluations show that students were more satisfied with the PBL-based course despite a comparatively heavier workload.

In addition to informing the lecture sections of the workshop, the findings encourage identifying relatable examples for use with students and the use of tools like ArcGIS Online to promote engagement and student learning.

Read, J. M. (2010). Teaching introductory geographic information systems through problem-based learning and public scholarship. *Journal of Geography in Higher Education* 34(3), 379-399. <https://dx.doi.org/10.1080/03098265.2010.490909>

This author incorporated a PBL approach to a community-based problem into an introductory GIScience course. Both student performance and course evaluations suggest that the PBL model and community-based problem had a positive impact on learning. Not only did the students learn technical GIS and problem-solving skills, they also learned research and professional development skills. A major challenge in teaching introductory GIScience is getting students to connect the geographic theory and principles with the technical skills needed to operate the software and perform analyses. The community-based problem helped to attract and maintain student interest because the content was interesting and relevant to them.

This article is used in the workshop to inform and support the lecture components as well as the activity in which participants develop PBL exercises. Workshop participants are encouraged to develop activities/assignments that give students the opportunity to engage in and solve problems that are relevant to them.

Liu, Y., Bui, E. N., Chang, C., & Lossman, H. G. (2010). PBL-GIS in secondary geography education: Does it result in higher-order learning outcomes? *Journal of Geography*, 109(4), 150-158. <https://dx.doi.org/10.1080/00221341.2010.497541>

In this paper, the authors evaluate PBL use in a GIScience class at a secondary school. They found significant difference in student achievement of learning outcomes between PBL-based and non-PBL-based classes. Students in the PBL-based class demonstrated analytical and evaluation skills, while students in the control class demonstrated memorization skills. The authors concluded that incorporating PBL results in achievement of higher-order learning outcomes in GIScience classes.

This article is used in the workshop to inform the lecture components and to emphasize the effectiveness of using PBL when designing activities/labs for students in university GIScience classes.

WORKSHOP CONTENT AND ORGANIZATION

DURATION (min)	SUBJECT	ACTIVITY	PURPOSE
10	Introduction	<p>Use round table introductions as an icebreaker.</p> <p>Ask participants to answer the following questions:</p> <ul style="list-style-type: none"> • What is your teaching background and experience in GIScience? • Why are you participating in the workshop? • What is your favorite thing about GIScience? Or share an interesting GIS-related fact. <p>Share workshop structure, outline, and learning outcomes.</p>	<p>To get to know participants and understand their expectations and goals for workshop.</p> <p>To get everyone on the same page with workshop expectations.</p>
15	Group Brainstorm and Discussion	<p>Ask participants to share challenges they have experienced with teaching GIScience.</p> <p>Have them discuss why these challenges persist, and consider how they can improve student learning experiences in GIScience.</p>	<p>To pre-assess how participants feel about teaching GIScience.</p> <p>To establish the relevance and emphasize the goals of the workshop.</p>
15	Introduction to Problem Based Learning	Describe PBL and the general benefits of incorporating the approach into teaching. Explain how PBL has typically been implemented in GIScience classrooms.	To share key concepts and research studies.
20	Solving a GIScience Problem	<p>Ask participants to:</p> <ul style="list-style-type: none"> • Determine on their own how they would solve the example problem (see Appendix A). 	To model collaborative problem solving in a GIScience context.

		<ul style="list-style-type: none"> • Find a partner, discuss individual choices, reasoning, solution(s), and determine the “best” approach/solution. • Ask pairs to join together and repeat the discussion. • Repeat until there is a whole group consensus on the approach/solution. <p>Ask participants to write out their thoughts on the problem-solving activity on sticky notes.</p> <ul style="list-style-type: none"> • Have them consider how they might use this type of activity in their own GIScience classrooms. • Compile the sticky notes at the front of the room and ask participants to comment on the major themes. 	To reflect on how the activity could be applied in the participant’s home classrooms.
25	Developing a PBL Activity	<p>Ask participants to work in small groups to develop a GIScience activity or lab assignment that incorporates PBL.</p> <p>Participants could deconstruct/rework existing lab exercises (e.g., the workshop facilitator could provide personal examples of traditional GIScience exercises that rely on step-by-step instructions rather than PBL).</p> <ul style="list-style-type: none"> • Ask participants to remove all “recipe” or step-by-step instructions and reword the exercise(s) to encourage students to find solutions on their own or in teams. <p>Participants should provide sufficient information for students to determine the required steps to solve the problem.</p>	To provide an opportunity to dissect an example problem and increase participant appreciation for PBL use in GIScience courses.

		<p>Alternatively, participants could develop an original activity/ assignment that relies on PBL using the example in Appendix A.</p> <ul style="list-style-type: none"> • Ask groups to refer back to the “Solving a GIScience Problem” activity or draw on their own learning experiences to inform this activity. <p>No matter what approach is taken for this activity, ensure that participants:</p> <ul style="list-style-type: none"> • Create and insert questions at the stages of the activity that would reinforce key concepts/methods and promote thoughtful engagement among students. • Encourage participants to discuss how many tips or hints students will need given the problem, course level, and available toolset. <p>During the activity, circulate to answer questions, discuss ideas, and assist participants where needed.</p> <p>Consider reviewing and sharing the products of this activity with all participants following the workshop for possible incorporation into future teaching.</p>	
5	Conclusion	Review the outcomes and major takeaways for the workshop.	To solidify the key points learned in workshop.
Total Time: 90 minutes			

PRESENTATION STRATEGIES

The ideal group size for this workshop would be 10 participants. A workshop would still be possible with more participants but more time would be required to adequately cover questions and discussions. All participants should have an intermediate to advanced level of expertise in GIScience. Consider sharing the annotated bibliography as an assigned reading list prior to the workshop so that participants will be familiar with the issues

involved. No materials other than a pen and notepaper are required for participation.

The presentation strategies employed in this workshop include lecture, group discussions and activities. Consider preparing a PowerPoint presentation to provide key concepts and findings related to PBL use in GIScience courses. Active learning activities are incorporated throughout to engage participants and provide a model to emulate in the university classroom. The group discussions and debrief questions provide opportunities for participants to reflect and to work with peers. Remember to bring copies of the activity sheets (Appendices A and B) for participants to work on during the workshop.

Consider providing a short handout to participants that summarizes the key concepts of PBL so that they can refer to it during the workshop activities and keep for future reference. Things to include in the handout might include a table that summarizes the general differences between a traditional and a problem-based classroom (see Drennon, 2005); a table that summarizes the benefits and risks of PBL compared to traditional methods (see Pawson et al., 2006); a graphic on the problem-solving method (see Pólya, 1957), and a flow chart of the PBL process (see Gukeisen, 2013).

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APPENDIX A: Solving a GIScience Problem

Pose a multi-step GIScience problem for which multiple approaches could produce a satisfactory solution. Workshop participants think through the problem independently and identify potential approaches/solutions. Participants then work in pairs to determine a preferred approach/solution. Groups combine and discussions continue until a whole group consensus on the solution is met.

This activity models the PBL approach and provides an example of a real world problem that could be used to engage students in the geography classroom or lab. Students learn through the process of determining and rationalizing the steps involved in achieving a solution. Deriving consensus from peer discussion encourages independent thinking *and* collaboration.

Example Problem:

A client is moving to a new city and needs to buy a house with a budget under \$450,000. You must find suitable housing options following several criteria. The client wants:

- to live in one of three specific neighborhoods
- to commute to work in under 15 minutes
- to be situated 10 minutes away from a school. Note: the client's youngest child is in elementary school and their eldest in high school
- to live near a park and/or greenspace

Questions:

- How will you determine which homes meet all the client's criteria?
- What datasets do you need?
- What additional information do you need, if any?
- How will you present this information to your boss (the realtor)?