Transformative Teaching: Adaptive Active Learning for Higher Machine Learning Education

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Abstract:

Active learning has gained immense attention in higher learning education in recent years. It is an instructional approach that engages students in the learning process through activities and experiences, as opposed to the traditional methods of learning where students passively receive information from teachers. In this project, we aim to address the pervasive challenge of passive learning in higher education, and assess the potential for improving active learning strategies within the domains of Bioinformatics and GIS (geographic information systems) by taking specific courses on machine learning in two disciplines. The project combines pedagogical theories such as Bloom's Taxonomy and constructivist principles with insights from seminal works by education scholars like Dewey and Freire. We propose comprehensive solutions, spanning from enriched educational contexts to dynamic assessments. This study endeavors to assess the impact of our innovations on student learning, culminating in a process report evaluating the collaborative journey of our interdisciplinary group. Through this endeavor, we aspire to contribute to the broader discourse on transformative teaching methodologies.

1. Aim and Goal of the Project

In response to the pervasive challenge of passive learning dominating the educational landscape, the overarching aim is to design a transformative shift to active learning in the bioinformatics and GIS domains, and introduce active learning activities to both lectures and laboratory sessions in machine learning courses. Through infusing interactivity and hands-on engagement into these educational contexts, the project seeks to suggest possible solutions to pave the way for an enriched, participatory learning experience that aligns seamlessly with contemporary educational needs. The ultimate objective is to contribute substantively to the discourse on effective teaching methodologies across diverse academic disciplines.

2. Background

The current pedagogical landscape in bioinformatics and GIS education often grapples with the prevalence of teacher-centered, passive learning methodologies. Teachers introduce various concepts and methods through lectures and students receive knowledge passively. Similarly, it is common for students to complete the exercises independently based on the detailed instructions in the lab sessions. Several studies have indicated that passive teaching and learning are no longer appropriate and effective (Bonwell and Eison 1991; Renkl 2002). In contrast, active learning activities engage students in higher-order thinking tasks such as analysis, hypothesis, synthesis, and evaluation. Several studies have shown the positive impact of active learning compared to traditional teaching methods (Livingstone and Lynch 2002; Musikhin 2014; Mathews and Wikle 2019). Although some educators are still constrained to the uptake of active learning and stick to conversational teaching methods, many good examples of the positive impact of active learning are increasing (Bradford 2010). For example, a study by Mathews and Wikle (2019) assessed various pedagogical approaches employed to teach GIS and technology courses and their results show that active learning pedagogies such as flipped classrooms, and collaborative and project-oriented assignments, are becoming more adopted and replacing the traditional teaching approaches.

Machine learning lectures, a pivotal component in both bioinformatics and GIS curricula, frequently adhere to traditional approaches, where instructors present concepts through slides, fostering a passive reception of knowledge among students. In the labs, students often work independently, following detailed instructions, limiting the scope for active engagement and deeper comprehension. These observations align with broader educational research indicating that passive teaching and learning models, as discussed by Bonwell and Eison (1991) and confirmed by Deslauriers et al. (2019), are no longer deemed optimal. The study by Deslauriers et al. (2019) specifically emphasizes the effectiveness of active learning compared to traditional teaching methods.

Furthermore, This project is inspired by educational philosophers such as John Dewey, who championed experiential learning and student-centered education, and Paulo Freire, known for his advocacy of critical pedagogy. Recent studies echoing Dewey's (1930) and Freire's (2020) principles on active and participatory learning will further inform our endeavor to revolutionize the educational landscape in both bioinformatics and GIS. In this project, we aim to infuse modern pedagogical active learning approaches into bioinformatics and GIS education by taking machine learning courses as a case study.

3. Design: Proposed Solution

To address the pervasive issue of passive learning in bioinformatics and GIS, a fundamental shift towards an active learning model is proposed, aligning with Bloom's Taxonomy for cognitive engagement (Bloom and Krathwohl, 2020). Both departments are running a course related to machine learning. Drawing from our own experiences in machine learning instruction, and also the literature review in pedagogical studies, the solution that involves a comprehensive restructuring of machine learning lectures and exercises is proposed according to the learning levels from Bloom's Taxonomy (Figure 1).

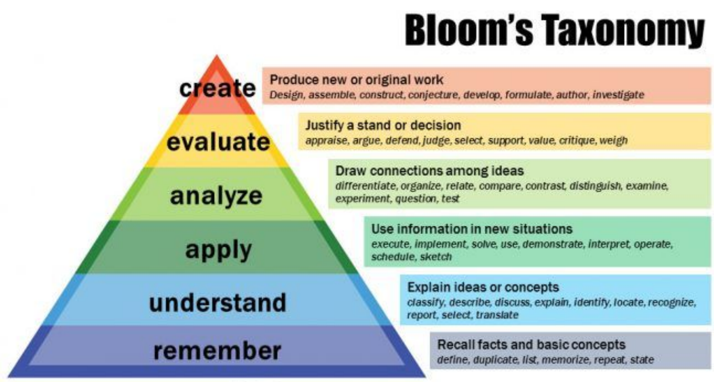

Figure 1. Bloom's Taxonomy indicating levels of learning
(source: https://www.bloomstaxonomy.net)

3.1 Educational Context:

Embed machine learning concepts within real-world bioinformatics and GIS scenarios, ensuring immediate relevance and practical application. Foster a collaborative environment that encourages student interaction and engagement at different learning levels of Bloom's Taxonomy.

3.2 Intended Learning Outcomes:

Develop systematic learning outcomes at different learning levels of Bloom's Taxonomy:

1. Remember and understand the concepts, mechanisms, and principles of machine learning algorithms.
2. Apply the concepts and algorithms to real-world bioinformatics and GIS scenarios and analyze the results.
3. Evaluate the performance of machine learning models and the results from a user perspective.
4. Create and develop machine learning models for different application problems, emphasizing the creation and evaluation of solutions.

The first two learning outcomes are already included in the previous teaching of this course. The remaining two are the intended learning outcomes that are newly proposed.

3.3 Teaching and Learning Activities:

Initiate lectures with brief theoretical foundations followed by immersive, hands-on exercises, catering to the understanding and applying levels of Bloom's Taxonomy.
Incorporate active learning techniques, such as group discussions and collaborative projects,

1. Initiate lectures with brief theoretical foundations followed by various learning activities such as video clips, in-class quizzes/polls, giving examples, asking questions, one-minute paper/ one-sentence summary, and mind map, catering to the remembering and understanding levels of Bloom’s Taxonomy.
2. For the learning levels of Apply and Analyze, the active learning activities can be debates, group discussions, collaborative projects, and student presentations, to reinforce theories, targeting the higher level of evaluating.
3. For the learning levels of Evaluate and Create, the active learning activities can be peer review, peer tutoring, and formulating application problems. New or original work can also be expected to be produced.

3.4 Pros and Cons:

This proposed solution integrates Bloom's Taxonomy to scaffold learning experiences, promoting cognitive engagement at various levels to create a more dynamic and enriched learning environment in bioinformatics and GIS.

Pros: active learning often leads to enhanced student engagement, deeper comprehension, and practical skill development since students have more control over their learning. It also makes the classroom more active and interactive. Compared with teacher-centered passive learning, such active learning is student-centered. Students can also learn from each other to improve their knowledge and understanding. In addition, students can access pre-class materials at their own pace and convenience, promoting flexibility in learning.

Cons: active learning may increase the workload for teachers. Teachers need to prepare many other things, such as videos, literature, quizzes, and discussion topics in advance, compared with the preparation only for lectures and exercises in passive learning. It also comes with its set of challenges, such as diverse skill levels of students, time constraints, and resistance to change for both instructors and students. Addressing all the mentioned challenges requires a proactive and collaborative approach involving educators, administrators, and students to create an environment conducive to successful active learning.

4. Assessment and Evaluation: Plan for Evaluating Student Learning

The assessment and evaluation plan is designed to holistically gauge the effectiveness of the proposed active learning solution in the machine learning courses in bioinformatics and GIS, emphasizing both formative and summative evaluation strategies.

4.1 Formative Assessment:

Methods: Regular quizzes, in-class discussions, one-minute papers, and short problem-solving exercises.

Purpose: To provide continuous feedback on students' understanding and application of machine learning concepts and mechanisms.

Implementation: Conducted throughout the course, these assessments serve as checkpoints for ongoing comprehension, allowing for timely adjustments to the teaching approach.

4.2 Summative Assessment:

Methods: Project presentations, comprehensive problem-solving tasks, and practical applications of machine learning in bioinformatics and GIS.

Purpose: To evaluate the overall mastery of machine learning principles and their application in real-world scenarios.

Implementation: Administered towards the end of the course, these assessments provide a comprehensive measure of student learning outcomes and the effectiveness of the active learning approach.

4.3 Observation and Feedback:

Methods: Regular classroom observations and student feedback surveys.

Purpose: To qualitatively assess the impact of the active learning model on student engagement, participation, and perceived learning experiences.

Implementation: Observations conducted throughout the course, coupled with feedback surveys, aim to capture students' perspectives on the effectiveness of the active learning initiatives.

4.4 Comparative Analysis:

Methods: Comparative analysis of student performance in the active learning model compared to traditional instruction.

Purpose: To assess the relative efficacy of the proposed solution in enhancing student learning outcomes.

Implementation: Analyzing student performance data from previous courses using traditional teaching methods and comparing it with outcomes from the active learning model.

This multifaceted assessment and evaluation plan integrates recent research findings on effective evaluation strategies. By combining both quantitative and qualitative measures, this approach aims to provide a comprehensive understanding of the impact of the active learning solution on student learning in the context of bioinformatics and machine learning.

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Process report:

Group Collaboration and Task Division: Throughout the course of our collaborative project, the group demonstrated exemplary coordination, effective task division, and seamless online collaboration, leading to a well-organized and productive process.

The group adeptly organized and executed the project through strategic task division, leveraging individual strengths and expertise. This approach ensured that each member could contribute meaningfully to the project by utilizing their unique skills given their time and schedule constraints. The group excelled in online collaboration, utilizing platforms such as Zoom for productive real-time discussions, brainstorming, and swift problem-solving. Additionally, the use of shared Google documents facilitated collaborative editing and centralized group contributions. The constant communication and responsiveness maintained by the group throughout the project fostered a positive and efficient working environment, showcasing a high level of professionalism and collaborative prowess.

Feedback Summary:

Group 3 offered insightful feedback on our project, focusing on aspects such as the title, project aim, argument consistency, and the flow of our content in the background and design sections. Their comments guided us in refining the title for better specificity and aligning it with the project's focused approach on integrating machine learning in two disciplines. The aim underwent revision to more precisely emphasize machine learning course design, ensuring a direct alignment with the project's goals.

In response to the feedback, we restructured the background section, placing increased emphasis on specific examples from current teaching situations in Bioinformatics and GIS. We introduced the example of a machine learning course, supported by relevant literature that underscores the principles of active learning in higher education. Group 3 and teacher comments on the design section prompted a reflection on the connection between our aim and proposed solutions, leading to a clear revision of Intended Learning Outcomes (ILOs) based on Bloom's Taxonomy. In addition, we also formatted the report to make the structure well-organized and easy-to-follow.

Our group wholeheartedly embraced this constructive feedback, resulting in substantial refinements to our project report. The focus on enhancing specificity, revisiting the aim and objectives for clarity, and linking the design and assessment components more cohesively greatly improved the overall quality of our project. The feedback proved instrumental in ensuring our report's alignment with its intended outcomes and addressing specific areas of improvement highlighted by Group 3 and the teachers.