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Board 42: A Comparative Analysis of Across Interdisciplinary Settings Integration Practice in Educational Data-Mining Class Using Community of Practice

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A comparative analysis of pedagogical approaches to foster interdisciplinarity in an educational data mining class using Communities of Practice.

Abstract

This working-in-progress research describes the design and assessment of two pedagogical approaches aimed at fostering a multidisciplinary graduate engineering course that bridges the domains of education and computer science. Leveraging the Communities of Practice framework, we examine how computer science students integrate new knowledge from education and computer science to engage in an educational data mining project. In the first course iteration, we investigated the creation of a multidisciplinary community by connecting students from both disciplines through a blend of problem-based learning instruction and traditional lectures. In the second version of the course, we established a multidisciplinary environment by bringing two instructors, one with computer science expertise and the other from education. To investigate the effectiveness of these approaches, we conducted multiple student interviews and classroom observations. We found that employing students as intermediaries had a localized impact on discipline integration, proving particularly effective for students with backgrounds outside of computer science. However, it fell short of achieving an overarching integration of education knowledge within the entire class. Furthermore, the co-teaching approach influenced class dynamics significantly, as instructors honed their brokerage skills and introduced crucial components to the multidisciplinary toolkit. These elements could be reinterpreted by students within the context of their projects, leading to a deeper integration of education and computer science disciplines. However, while students did acquire more knowledge from their less familiar discipline, they didn't always achieve a comprehensive practical understanding of the class outcomes. The paper also discusses the merits and drawbacks of employing both approaches to build an interdisciplinary class. The benefits, pros, and cons of having both approaches to building an interdisciplinary class are discussed.

Introduction

Collaborative skills have been widely recognized as the primary skills for success in 21st-century society (National Science Foundation, 2020; Engineers Australia, 2022; Engineering Council, UK, 2020). In the field of STEM professions, the development of these collaborative skills is critical to work effectively in interdisciplinary environments (Almeida *et al*., 2021; Khosronejad, Reimann, & Markauskaite, 2021). Learning to collaborate requires individuals to adapt their language and negotiate their participation with co-workers who have a multidisciplinary background and expertise. One interdisciplinary environment is Educational Data Mining (EDM) and data analytics, which is increasingly important in educational and research practices. Professionals in this field need to integrate disciplines, such as education or learning science, with data mining techniques typically associated with computer science or data science. To develop multidisciplinary skills, students must be exposed to learning experiences where they interact and integrate various disciplines. In particular, in the interdisciplinary context of EDM, there must be an integration between the educational community and computer sciences, enabling students to learn and integrate knowledge, techniques, concepts, and tools from both disciplines.

To prepare students to achieve this goal, we designed and implemented an EDM course guided by the Community of Practice (CoP) framework proposed by Lave and Wenger (1991). This framework suggests that two CoPs can interact through their practices mediated by boundary objects and brokers. Boundary objects are artifacts, procedures, and tools that can be used by individuals in both communities to disseminate ideas between them. Brokers are individuals who are members of both communities and can transfer knowledge, tools, and ideas from one community to another.

Applying the principles of the CoP, we designed the EDM course with two different approaches. First, in spring 2022, we implemented an EDM class as a multidisciplinary encounter by bringing together students from both disciplines to collaborate on EDM projects. Students had to transfer their previous knowledge learned in their respective disciplines (education and computer science) to this new community. In the second approach implemented in Spring 2023, instead of having students from multiple disciplines work together, an expert from the education community who was knowledgeable in EDM worked as a co-instructor. The same instructor taught the versions, but the students were different. Through an analysis of student interviews, class observations, and interviews with former students, this research investigates the impact and creates a body of knowledge regarding the pros and cons of these two approaches. The following research questions guide this research:

RQ1. How do students incorporate learning outcomes from the complementary background needed in the EDM class based on the instructional teaching model?

RQ2. How do students transfer their prior knowledge to the EDM based?

By addressing these questions, we aim to first understand the advantages and disadvantages of developing EDM courses through these two different approaches and, secondly, to provide insights into best practices for instructors.

Background

Educational Data Mining (EDM)

EDM is a discipline aimed at applying and developing new methods to analyze large datasets generated within educational contexts, providing insights into students' interactions, learning patterns, participation, and contribution (see more detail at educationaldatamining.org).

Data scientists strongly promote this field, and it has grown as researchers and practitioners recognize its potential to interpret, model, predict, and enhance student learning under current and new teaching practices. Despite the positive integration of data science techniques, procedures, or tools into EDM, integrating educational knowledge, concepts, tools, and procedures remains a significant challenge. For example, a study Paquette et al., 2020 revealed that only a small percentage of EDM research incorporates students' demographic information, a critical aspect of any educational study.

This unbalanced or asymmetrical integration of the educational is also noticed in how the students are being prepared for this discipline. In fact, EDM community has primarily originated within the computer science domain, lacking sufficient integration of educational knowledge and practices. Indeed, educators still encounter considerable challenges in participating in this community due to barriers and perceptions of the need for advanced programming skills and proficiency in sophisticated software. Using the Community of Practice framework, we designed an EDM to foster a more balanced integration of the educational and CS disciplines in this EDM community. Next, we introduce CoP and how it is operated to design the EDM course.

Theoretical Framework: Community of Practice

Community of Practice is proposed by Lave and Wenger (1991) to provide a context where social constructivism learning takes place. A CoP is formed with people who share purposes and methods and provide a context where they can negotiate, participate, and share different tools, meanings, and concepts, among others (Wenger, 1998). A key concept introduced by Lave and Wenger (1998) is Legitimate Peripheral participation (LPP), which describes the process of an individual joining a new competition and, by practicing mastering knowledge and skill that will re-negotiate their participation from a newcomer to full participation in the community.

CoP is funded with the premise that humans are social by nature, the knowledge is a competence and participation, and the learning procedures are meaning (1998). Indeed, different from the traditional constructivist perspective, in CoP, learning seems to be an outcome of involvement, engagement, participation, and practice in social activities. Indeed, CoP is a framework that highlights the social engagement of individuals from diverse backgrounds. We have used CoP to study interactive and multidisciplinary graduate classes successfully (Diaz et al., 2022, 2023, 2024)

EDM through CoP lens

EDM serves as an interdisciplinary frontier that articulates data science and education. Applying the Communities of Practice (CoP) lens, an EDM is a community discipline that emerged as the intersection of two existing CoPs—Education CoP and Data Science CoP.

The interconnection between the EDM community and Educational and Computer Science (CS) CoPs is facilitated through boundary objects and brokers (Wenger, 1998, 2002). Boundary objects are tools, procedures, knowledge, and software shared across both communities. For example, the software R (REF), commonly associated with the CS community, is used for data analysis in the EDM. Brokers are individuals who belong to both communities, capable of transferring ideas between them. For instance, students in education can share knowledge about ethical considerations in working with K-12 students and obtaining authorization from school districts to the EDM community.

The objectives of the EDM course are to cultivate an environment where students can acquire knowledge and develop skills associated with data science techniques, advanced software usage for data analysis, and learning theories and educational practices to interpret and design educational interventions.

Considering that it is very likely that participants in an EDM course may come from strong data science or education backgrounds, there are two considerations to accomplish the learning outcomes of the EDM course. First, students must learn concepts and skills that may not be part of their background, such as mastering main learning theories for computer science students or social network analysis techniques for students with an educational background. Secondly, the course must enable students to effectively transfer their prior knowledge and experiences. Indeed, it is critical that students are able to bring their previous knowledge and experience to EDM community as they also learn new concepts from other disciplines that they may not be familiar with.

Method

The EDM course under study is offered by the Computer Science department of a research-intensive mid-Atlantic American university and is available at the graduate level as an elective for both the College of Engineering and the College of Education. The class size fluctuates between 7 and 45 students, and the course is offered every spring semester. The iterations of the course were analyzed under a multi-case study to assess the effectiveness of the different approaches used for EDM courses.

Data sources

Class observation. Extensive data collection was made throughout the course. Every class of both semesters had at least one well-trained evaluator taking a class on the student interaction and dynamic of the class. Each class observation was documented in a memo, capturing general information such as date and class topic and insights into class dynamics, student participation, and emerging themes recorded based on CoP concepts. For example, write down instances where students demonstrated brokerage capacities by contributing previous concepts associated with either Education or Computer Science. The first author of this paper carried out all class observations.

Students' interviews. All students were invited to be part of the interviews in the middle of the course and at the end. The individual interviews were conducted by the researcher teams in 2022 for the second author of the paper, a Ph.D. level professor, and in 2023 for a research assistant trained by the first two authors of this paper. The interviews were semi-structured and conducted by ZOOM. The automatic ZOOM transcripts were revised and accuracy corrected for the second author of this paper. Every interview was around 20-30 minutes.

Data Analysis

The qualitative data was analyzed using an inductive thematic approach. We were using the codebook that we developed from the study of other graduate engineering classes (Diaz et al., 2024) that are also part of this NSF project. Even though the primary analysis was inductive, we were also open to some emerging themes that could appear.

Results

Not all data had been analyzed at the time of writing this manuscript. Here, we describe the initial results. We hope that more findings will be provided during the conference.

RQ1. Students learning outcomes

The integration of new concepts from computer science and education needed to participate in the EDM community effectively varied based on the instructional design employed.

In the first instructional model, knowledge incorporation primarily occurred when students collaborated in one-on-one team projects formed by peers with different backgrounds. Students working independently on projects interacted in smaller environments to effectively build a small community that represents the interdisciplinary component of the EDM community. Given the course's higher enrollment of CS students and few education students, interdisciplinary integration was localized primarily within students who had the opportunity for interdisciplinary teams and ineffective with students working only with CS peers.

Teams formed exclusively with students from a single discipline showed a lack of integration of the other disciplines. Furthermore, during the interview, we asked them about the education concepts learned; these students broadly described specific concepts introduced by the instructor but struggled to provide concrete examples of how these concepts could be applied to their research interests. In the final class project presentation, we also noticed the lack of interdisciplinary integration and where education concepts were minimally discussed.

On the other hand, the student with multidisciplinary participation, as observed during interviews, showed a deeper interdisciplinary integration of concepts into their practice. For example, a CS student mentioned that from teamwork, they learned different processes and theoretical frameworks applicable to their research. He provides a concrete example directly in their project, such as employing the Community of Practice framework to analyze student participation in classes. Additionally, informal discussions within the class and with his teammates led to the exploration of concepts not used directly in the class project but that were useful for his independent research. For instance, the student provided a concrete example of the Zone of Proximal Development, a concept derived from Vygotsky's social constructivism theory, learned in the instructor's lecture. This concept is now employed in the student's research with adaptive tutoring systems, offering valuable insights into the role of hints within these systems.

Finally, we analyzed if class interaction between student affects their interdisciplinary integration. For instance, throughout classes, the instructor asked open questions for students to be discussed with those seated nearby. During the interview, the education student commented that he has strong interaction with two CS students (outside of his team project classmate) and always sits in the area, and all the class conversations occurred with the same students. However, in the interview, the CS student identified that they had highly interacted with the education student and described that all the education concepts learned in the class came from the instructor’s lecture. In the following questions, we asked the student if he had the opportunity to interact with other students with a different background or with people with more education backgrounds. He mentioned that he did not remember having interaction during the class or with the project-related task with his educational background.

Interdisciplinary integration in the second instructional model primarily occurred at the class level. In this iteration, all students had a CS background. During individual interviews, students emphasized the importance of education concepts such as ethics and learning theories in guiding their research in EDM. When asked about the concepts learned from education, students commonly referred to ethical aspects, involving the Institutional Review Board (IRB) process for approving their research, understanding students' previous experiences, and recognizing the importance of contextual aspects in designing or analyzing their research.

While students acknowledged the significance of these concepts, when prompted to provide specific examples of how these concepts could support their research, only one student was able to offer a concrete example. This student, influenced by the constructivism theory discussed during lectures, commented on the importance of incorporating students' profile information in a project designed for second-language learners. The problems they could potentially face were identified based on the student's first language, a specific example previously discussed by the instructor. Indeed, the findings indicated that students had a broad understanding and recognized the general value of incorporating educational components in their research. However, a gap was observed in operationalizing these concepts, highlighting the need for further exploration of how to effectively apply these theoretical principles in their specific research endeavors.

RQ2. Students' knowledge transfer to the EDM class

Students incorporate knowledge through the use of boundary objects that connect their previous knowledge with the application of EDM research. Furthermore, students transfer their knowledge centered around boundary objects, with software and tools serving as boundary objects for CS students and procedures and contextual learning as boundary objects for education students. The effectiveness of integrating these boundary objects varies across different teaching modalities.

In the first version, a lack of representative boundary objects from both disciplines was observed. The emphasis in the class was mainly on tools associated with CS discipline, with fewer examples integrating boundary objects commonly used in education. A successful case was in Class 11 (02/16/2023) during a workshop on Bayesian knowledge tracing models. The instructor provided an extensive dataset and explained what to do, usually using R or Python; however, in the next class, the instructor started by commenting that he received some questions about the assignment and started providing an explanation of how students could use Excel or spreadsheet to complete the assignment without needed some advance software. This is a positive example of providing an alternative boundary object that facilitates students' previous knowledge integration in the new community.

In the second model, where different instructors delivered the classes, each instructor naturally introduced different boundary objects familiar to their respective disciplines. For instance, in the Social Network class led by an instructor with more expertise in education, alternatives to R, such as Gephi or Socicv, were recommended. These software options are specifically designed for social network analysis, reducing the need for extensive programming knowledge to perform calculations.

Discussion

Our preliminary results show that an instructional model fostering collaboration among students, where they take the lead in negotiating their participation, is an effective approach to creating interdisciplinary classes. This is effective when students form small communities for one-on-one participation. However, this model proves less effective in achieving full integration between both disciplines and establishing a cohesive class environment. Indeed, a deeper articulation of interdisciplinary concepts was accomplished in a multidisciplinary team, but it was a very limited interdisciplinary environment, and there was almost no interdisciplinary integration with those students who could not be part of a multidisciplinary team project.

On the other hand, having two instructors without multidisciplinary interaction creates an interdisciplinary integration at the level of all students participating in the class but is less effective in operating those concepts into real research projects.

Limitations

As researchers, we tried to conduct as much extractive research as possible. However, we are aware of some limitations. First, the class size. The variation in class size between the two iterations represents a potential limitation. Despite efforts to encourage more students to enroll, the second iteration had a lower enrollment. Although the class size is relatively small, it remains within the expected parameters for a multi-case study (e.g., Campo et al., 2023; Huang et al., 2023; Eberle & Hobrecht, 202).

Additionally, the one-year difference between the two iterations could introduce a potential bias in instructor experience. However, the instructor had taught the course at least four times before the first iteration with students. As a result, the impact of the variation associated with the experience of teaching the class is lower.

Conclusions

Our preliminary findings suggest that differences in instructional design can significantly impact how interdisciplinary integration forms within a class. For courses where there is a similar number of participants with a strong background in each discipline, utilizing a single instructor with small teams (one-on-one participation) mixing students appears to be an effective approach.

When there is an imbalanced representation of students' expertise backgrounds in the class, using multiple instructors who are legitimate members of the course can foster integration on a larger scale. This approach also facilitates the transfer of previous knowledge to the class. However, without experience where students independently negotiated participation in multidisciplinary environments, students have a lower operationalization of integrated concepts.

Ideally, a combination of both approaches could prove beneficial for students. Different instructors recognized as legitimate members of each discipline can create an interdisciplinary environment within the entire class. Additionally, having a project with multidisciplinary teams allowing students one-on-one interaction while working on real projects enables them to negotiate their participation with peers, resulting in a deeper integration of the involved disciplines.

Boundary objects play a critical role in how interdisciplinary collaboration occurs, and the course must offer and promote concrete boundary objects (e.g., software, procedures, knowledge) from each discipline. Although some software may be predominantly used in the new CoP environment, instructors can highlight alternative boundary objects that enable students to accomplish the tasks required in the course.

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