COMBINING PROJECT-BASED LEARNING AND SCIENTIFIC WORK

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Abstract

Working scientifically and writing a conference paper is usually part of PhD programs, but not part of a regular study program for an undergraduate or master's degree. In a master's degree class for computer science, a concept to combine scientific work with project-based learning was developed and has been carried out twice. The students had to learn the professional skills of the subject social network analysis and gained methodological skills. They had to conduct a research project and to write a conference paper. In the course evaluation, the students state their high learning outcomes, but also they find that the projects are a lot of work and they describe their difficulties with this kind of work. They are used to writing project reports and bachelor's theses, but not to writing conference papers. Therefore, this concept was professionally and methodologically a new and beneficial experience for them.

Motivation

In the master's degree classes of the computer science department, not only professional competencies but also methodological competencies are taught. However, there is no specific preparation for a PhD program. The students write project reports and master's theses, but normally they do not write a paper for a scientific conference. This was the motivation to offer a course for students to work in groups on a research project with the aim of writing a paper for a real conference.

There is literature available on the mentoring process, which accompanies students to gain research skills. Jiao et al. (2011) examined mentoring as a form of researcher development. In their study, "two academics assembled a research team for a collaborative project and, while they oversaw the project, roles were assigned to individuals through discussion and consensus" (Jiao et al., p. 42). Mullen and Fletcher (2012) wrote a handbook of mentoring and coaching in education. The study of Ferguson & Ellis (2022) "found that mentoring relationships enhanced students' research capabilities, resulted in students identifying themselves as researchers" (p. 235).

Likewise, project-based learning is a well-known concept. Kokotsaki et al. (2016) wrote a systematic literature review about this field. Inquiry-based learning is described as an educational strategy to gain knowledge (Pedaste et al., 2015, p. 48). Inquiry-based learning is a pedagogical approach in which students learn by actively exploring and investigating real-world questions or problems. It is a student-centered approach of learning that emphasizes the role of the learner in constructing knowledge and understanding. The process of inquiry-based learning involves several key steps, including posing questions, collecting and analyzing data, and drawing conclusions based on evidence. This strategy is similar to the procedure that is illustrated in the following. However, the case study described in this paper presents a teaching concept whose primary aim is not to gain knowledge but to practice relevant methods of use in their further education.

The focus of this paper is neither on the mentoring process nor on the outcomes of project-based learning. This paper describes the mediation of research skills on a high level in the course of a project. The aim of the course was to write an academic paper about a research project. The paper describes the composition of the master's course and the experiences that were gained in two runs of that course. The next section gives an overview about the learning content and the professional and methodological competencies that were taught in the course. The following section describes the teaching concept. Afterwards, the results and observations of the teachers are noted. The paper ends with a conclusion that discusses some implications, e.g., the trade-off between finding an adequate way to give students enough input while not restricting their creativity.

Learning Content

In this section, the content of the course is explained. First, the professional content of the subject social network analysis is briefly described. This is followed by a report about the methodological skills that the students have practiced.

Professional competencies

Social Network Analysis (SNA) is an interdisciplinary field of study that investigates social structures and relationships by analysing the patterns of connections among individuals, groups, organizations, or even countries. SNA enables researchers to visualise and quantify the complex webs of social interactions that shape human behaviour and outcomes. SNA draws on theories and methods from sociology, psychology, anthropology, economics, computer science, and mathematics to study social networks.

A social network consists of a finite set or sets of actors (depicted as nodes) and the relation or relations defined on them (depicted as ties) (Wassermann & Faust, 1994, p. 17). SNA focuses on the structure of ties rather than the attributes of nodes. This means that social network analysts are interested in the patterns of social ties among individuals rather than the characteristics of the individuals themselves (Granovetter, 1973, p. 1360). For example, SNA can be used to study how information flows through a group of people, how ideas are diffused in a community, or how influence spreads among decision-makers (Burt, 1976, p. 93).

SNA is a useful tool for studying a wide range of social phenomena, from the spread of diseases to the adoption of new technologies, from the emergence of social movements to the evolution of organizations. SNA has been applied in various fields, including sociology, political science, communication studies, marketing, management, and health care (Fu et al., 2017). It has also been used to study online social networks, such as Facebook, Twitter, and LinkedIn (Schötteler et al., 2022).

In recent years, SNA has become increasingly popular due to the availability of data and software that facilitate the analysis of social networks (for example Borgatti et al., 2002). With the rise of digital technologies, people are more connected than ever before, and these connections generate vast amounts of data that can be analysed using SNA. Social media platforms provide researchers with access to large-scale data on social interactions, enabling them to study social networks at unprecedented levels of detail.

In our master's course "Social Network Analysis (SNA)", the students learn the following skills as professional competencies:

- To understand the concept of social network analysis,
- To perform social network analysis,
- To calculate and interpret metrics,
- To analyse and visualise data,
- To present and evaluate results.

Methodological competencies

A group of students who want to work on a scientific project should generally follow the following steps (Kumar, 2018, p. 39):

- Topic selection: The group should select a topic that is relevant to the course topic. Within the course, they gain sufficient knowledge to conduct a high-quality project.
- Planning: The group should create a plan that includes the different steps of the project, the responsibilities of each member, the timeline, and the deadlines.

- Research: The group should conduct thorough research to become informed about the current state of research on their topic. Therefore, they were given the task to write literature excerpts (Booth et al., 2016).
- Designing the research: The group should develop a research design that includes a hypothesis model, appropriate methods and tools for data collection and analysis (Marder 2011, p. 18).
- Data collection: The group should collect the necessary data and document it properly.
- Data analysis: The group should analyse the data and interpret the results.
- Writing the report: The group should write a report that includes the objectives, the research design, the methods, the results, and the conclusions of the project (Maner, 2000).
- Review and proofreading: The group should check the report for grammar and spelling errors as well as factual errors. Each member of the course writes reviews for papers of two other groups to provide feedback and suggestions.
- Presentation: The group should prepare a presentation to present their results. They should practice to ensure that they could deliver their presentation effectively and within the allotted time frame (Alley, 2013).

Teaching Concept

Professional and methodical content were taught systematically together. The steps are numbered in the following order. The observations and results in the next section are assigned to these numbers.

1. In the first lesson, the professional input contained the theory of social network analysis. The students learned what social networks are and how to analyse them. The methodological input was how to formulate a research question. Students got their first task: the definition of their research question.
2. The students got input how and where to find relevant literature and how to write literature excerpts. The next task was the systematic search for relevant literature in the particular research domain. Every student had to write two literature excerpts. All excerpts were uploaded to a forum, so that all students had access to an amount of literature excerpts referring to social network analysis. These excerpts were the basis for the section “related works” in their conference papers.
3. The next professional input was the explanation of relevant metrics and their meaning in social network analysis. The students learned how to conduct a social network analysis, which tools they can use for it, and how to interpret

the metrics. The students learned how research exposés were structured and had to write their own exposés.

4. After the discussion of the exposés with the teachers, the students prepared presentations of their research projects. These presentations were discussed with the other groups and helped the students to focus on their own work.
5. The students heard explanations about statistical methods for their data work. They learned how to produce and interpret statistical metrics. They learned what they have to consider for their data collection when they execute surveys, interviews, observations, and data scraping. Their next task was to plan and execute their data collection and to design a hypothesis model.
6. Next, the students learned how to structure a scientific project. They were informed about the expected content in the abstract and the introduction section. Their next task was to write the table of contents, the abstract, and introduction section for their conference papers.
7. The students got feedback on their written text. Then, they had to write the full paper for a regular conference in the information systems domain. They had to use the conference template and had to meet the requirements for the authors of this conference.
8. After all of the papers were submitted, the students received feedback from reviewers. They heard input on criteria, which are relevant to assess a paper. Each student had to write two reviews of papers of other groups.
9. Based on the reviews received, the students improved their papers for the final submission. They presented their work according to conference standards with plenary discussions.

Every week, there was a meeting between the teachers and each students' group to discuss the results and talk about the next steps.

Results and Observations

This section presents the results and observations assigned to the steps described the previous section.

Step 1: Formulate a Research Question about Social Networks

At the beginning of the course, a few of the students had difficulties in understanding the concept of social networks. Some were confused about the different concepts of social media and social networks. Thus, a challenge in this step was to emphasize that social media and social networks are closely interrelated, but ultimately distinct concepts.

In the first run, the research questions of the different groups differed. In the following list, the students' initial research questions are presented:

1. "How do the Twitter interactions between German Members of Parliament change before and after the election? What differences in intra- and inter-party communication can be shown? Can a shift towards the successful coalition be derived from these findings?"
2. "What effect does the network position in the answer network of the Stack Overflow site have on the duration until the first answer is received?"
3. "How do different metrics of social network analysis related to an actor influence the timing of the information gain of a scientifically relevant discovery on the social media platform Twitter, using a specified network as an example of the Higgs boson?"
4. "How does the network position in music collaboration networks relate to the popularity of the tracks? How does the network position in music collaboration networks relate to the popularity of the artists?"
5. "What influence does the network configuration have on the offensive team performance using selected NBA basketball teams as an example?"

During the second run of the master's course, the paper pertaining to research question a) of this list was already published. This obviously influenced the new groups on their choice of their research domains. All groups of the second run formulated a research question that focused on Twitter data analytics in a political context.

Very interesting is the fact that all groups decided to conduct data analytic work on the internet. Other possible methods of raising data are surveys, interviews, and observations. This can possibly be explained by the fact that all students had a computer science background. Thus, they did not consider any other method than scraping digital data traces, given the fact that scraping is often perceived as less time-intensive than conducting classical surveys. However, it should be noted that this assumption might be questionable, depending on the underlying study context.

The definition of the final research question was a process, which lasted weeks. There were more iterations necessary until the research question was adequately formulated for all groups.

Step 2. Create Literature Excerpts

The forum for the literature excerpts was readable for all students. The students got marks for their excerpts because this was a task to be done alone and not in the group. However, the structure of all excerpts was very similar, so that there were no great differences in the assessment. The students obviously looked how others had solved the task and oriented their work to the files in the forum.

Step 3. Write a Project Exposé

The requirement to write a project exposé helped the students to integrate their previous work and to concentrate on their specific research focus. This document helped the teachers and the students to gain a clear understanding of the research project. In many student teams, numerous iterations of this document had to be done after repeated teacher coaching.

Step 4. Present Research Project

The presentations of the research projects of all groups were very interesting for all other groups. They could easily identify similar problems and exchanged ideas about possible solutions.

Step 5. Analyse Data and Formulate Hypothesis Model

Because all groups voted for data scraping, the explanations about other methods of data collection were not necessary. Methods of statistics and the knowledge about formulating a hypothesis model were part of the prerequisite bachelor's programs. Surprising was the fact that the students had less knowledge about these methods. Recapitulation of relevant statistical knowledge was necessary. Some weekly meetings were necessary until the hypothesis model was correctly formulated and the data work was done.

Step 6. Write Beginning Sections

The table of contents of the conference paper was similar for all groups because of the similar structure of their research projects. The students got detailed feedback on their written texts. This was a valuable background for the writing process. The students stated that this kind of writing differs from that kind they are used to.

Step 7. Write Conference Paper

It was a completely new experience for the students to count the words of a report as is usual for conference papers. They had to select which contents are necessary, which figures and tables are a valuable part of the paper, and which contents can be omitted. Until this moment, they were used to explaining their work elaborately. They had to learn to write all essential details in a limited amount of words.

Step 8. Peer Review Others' Papers

The production of reviews was the second mark a student got for an individual output. This fact motivated the students to write qualified feedback with suggestions for solutions. At this time, all students had advanced knowledge in the

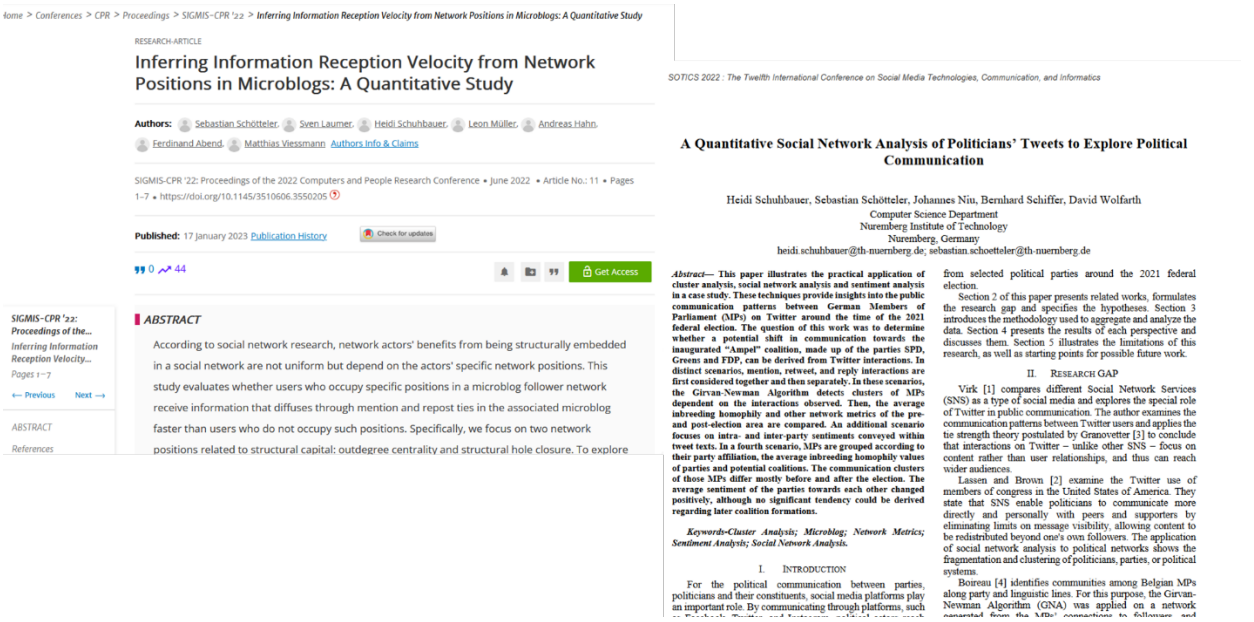
topic of social network analysis and could thus provide valuable feedback. The two teachers also wrote separate reviews for each paper.

Step 9. Revise and Submit Presentations

It was astonishing that every group produced a qualified answer to their research question. Two of the papers have been published (Schötteler, 2022; Schuhbauer, 2022), and a further paper is currently in the queue. Nevertheless, we must admit that a – partly fundamental – revision through the professor and the PhD student had to be done to achieve this success (Figure 1).

Figure 1

Published articles



Conclusion

In the course evaluation, the students stated their high learning outcomes. All appreciated teamwork. To conduct a research project was a completely new experience for them. They got their first experience with scientific project work intended to be presented at a conference. However, they stated that the projects were a lot of work and they described their difficulties with this kind of work. They are used to writing project reports and bachelor's theses, but not to writing conference papers.

The teachers experienced tension during the mentoring process between giving strict guidelines and giving only hints of solutions. When the teachers gave too many suggestions, the students oriented their work on them and the results were similar. This can be clearly observed in the choice of the research questions. In the first run, the students had no example works of other students to orientate towards. Their research questions differed from each other. In the second run, all groups worked on similar topics. The second great challenge was the selection of an adequate data analytics method. This selection depends on the formulated research question and the acquired data set. Hence, the students could not adapt methods of similar projects. The selection of the data analytics method required knowledge about the method itself and the specific research topic. However, the students found it very challenging to conduct a self-reliant research project. Therefore, they expressed the wish to receive presentations of example projects. The tension is to find an adequate way to give the students enough input but not to restrict their own creativity.

A questionnaire was done to evaluate the course by the students. The students assessed the structure of the course as logical and helpful. However, they stated that a lot of background knowledge was a prerequisite. It was covered by their bachelor's program, but they had not used it until now and had forgotten a lot of it. The aim to write a paper that is to be published at a regular conference is a great motivation for them. Therefore, this concept was professionally and methodologically a new experience for them. Moreover, many course participants stated that the knowledge gained is likely to help them in writing their master's thesis. Furthermore, the course may nudge its participants to seriously consider choosing research as a career path. Indeed, one of the course participants is now a PhD student at our computer science department. Another course participant decided to deepen his research conducted in the master's course by means of a subsequent master's thesis on the addressed topic. In summary, these developments indicate that this course fills a relevant gap in our department and helps to bridge the path from a master's student to a research associate.

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