Empowering Undergraduates in Empirical Research Methods: an Experience Report

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ABSTRACT

Context: Undergraduate students often struggle with research methods and methodologies crucial for their development. Effective training is essential to bridge the gap between theory and practice. Objective: This course aimed to empower students with a solid understanding of scientific research, enhance their research planning skills and proficiency in empirical methods, and improve their scientific writing and presentation skills. Method: An in-person Empirical Software Engineering course was conducted for 17 undergraduates over 60 hours in a semester. It included theoretical classes, practical activities, seminars, evaluations of empirical articles, and peer evaluations of research projects. Results: Students reported high satisfaction with the course, particularly in topic approach, content references, and achieving objectives. Areas for improvement included clarity of course objectives and developing critical thinking skills. Most activities were found useful, though some were challenging. Conclusions: The course successfully developed research skills among students. Improving clarity of objectives and support for complex activities can further enhance the learning experience. This report provides insights into empirical research education in software engineering, highlighting successes and areas for improvement.

CCS CONCEPTS

• **Applied computing**; • **Education**; • **General and reference**; • **Cross-computing tools and techniques**; • **Empirical studies**;

KEYWORDS

Scientific Research Methods, Empirical Software Engineering, Empirical Methods, Teaching, Experience report.

1 INTRODUCTION

Teaching empirical research methods to undergraduate students in software engineering is crucial but often challenging [11] [5]. These methods can be taught mainly in three ways: (1) integration in software engineering courses, (2) as a standalone course, and (3) as a component of a research methods course [22]. Many students, especially undergraduates, struggle to understand and apply research methods essential for bridging the gap between theory and practice. The research skills students acquire can help them pursue further education, solve real-world problems, and uncover the truth. Furthermore, research methods can be applied to everyday issues, as students who learn to analyze problems systematically and objectively are more likely to make successful and confident decisions [5].

We created a scientific research methods course for undergraduate students, in which some methods of Empirical Software Engineering (ESE) are taught as a component of this course to address this need of training students. The course aimed to teach students the basics of scientific research, improve their research planning skills, and make them proficient in different empirical methods. We also focused on enhancing their skills in scientific writing and presenting their research projects. In this course, we take a similar approach to [11], where we guide students in learning scientific work through hands-on scientific activities. This hands-on approach, according to Dale's cone of learning [2], leads to students retaining 90% of what they say and do after two weeks.

The main problem we addressed was students' difficulty in mastering research methods [5]. This difficulty often leads to a shallow understanding of empirical research, which affects their ability to conduct meaningful studies. To solve this, our course combined theoretical lessons, practical activities, and peer evaluations to give students a thorough understanding of empirical research. This approach is similar to project-based learning methods used in other studies to teach empirical software engineering [11] [6].

This paper provides an experience report on teaching empirical research methods in an undergraduate course with 17 students. This hands-on approach aims to enhance critical thinking, creativity, and the development of essential skills such as research planning, scientific writing, and presentation. The course included theoretical lessons, practical exercises, and seminars, with ongoing evaluation through project submissions and peer reviews. This approach aimed to give students a solid foundation in empirical research methods.

Our goal was to create an engaging and effective learning environment that taught students and gave them hands-on experience with research methods. The course was conducted over a semester, with weekly classes covering literature reviews, surveys, experiments, and case studies. Students participated in seminars, evaluated research articles, and reviewed each other's projects.

We analyzed the positive aspects and areas for improvement in this methodological approach, the benefits and challenges encountered, the ease of use and usefulness of the practices and techniques from the students' perspectives, and their self-reported experiences and performance in peer evaluations.

Our results showed that students were very satisfied with the course, especially with how topics were presented, the quality of the materials, and the course's objectives. However, there were areas for improvement, such as making the course objectives clearer and helping students develop better critical thinking skills. These findings align with those from other studies on teaching empirical methods, which also highlight the importance of clarity and critical thinking in research education [1] [16] [15]. Despite some challenges, most activities were useful and contributed greatly to the students' research abilities.

In summary, the course successfully improved students' skills in empirical research, though some areas could be refined to enhance the learning experience further. This report offers insights into teaching empirical software engineering and highlights the course's strengths and potential improvements.

This document is structured as follows: Section 2 discusses background and related work; in Section 3, the methodology approach applied to teach empirical software engineering is explained; in Section 4, the research design is described; in Section 5, the answers to our research questions are provided; and, finally, in Section 6, conclusions and future work are discussed.

2 BACKGROUND AND RELATED WORK

2.1 Empirical software engineering

Empirical software engineering (ESE) is a research discipline dedicated to improving software engineering practices through systematic observation, measurement, and experimentation [7]. It aims to provide scientific evidence that guides practitioners in making informed decisions, thereby enhancing software development's efficiency, quality, and reliability. ESE employs various empirical methods, such as controlled experiments, case studies, surveys, and systematic literature reviews, to gather qualitative and quantitative data on software engineering processes, tools, and practices [22].

Historically, ESE has evolved by adopting different empirical methods, ensuring that findings are robust and applicable in diverse contexts [7]. Contemporary ESE covers studies conducted in real-world environments, controlled settings, and computer simulations. This comprehensive approach bridges the gap between theoretical research and practical application, making software engineering more objective and evidence-based. Ultimately, ESE advances the field by providing actionable insights that drive the development of better software engineering practices and technologies.

The ESE community has developed and maintained empirical standards for software engineering [18]. These empirical standards reflect the collective expectations of the SE community regarding research methodology and reporting.

2.2 Related Work

Teaching Empirical Software engineering. The works of Kuhrmann [11] and Felderer and Kuhrmann [6] focus on improving students' understanding and applying empirical methods in software engineering education through practical, hands-on approaches. Kuhrmann (2017) integrates empirical methods into the curriculum with a structured approach that balances theory and practice. Felderer and Kuhrmann emphasize project-based learning, where students engage in mini-projects to apply empirical methods to real-world problems, enhancing their critical thinking and research skills.

Our work is similar in emphasizing practical learning and integrating empirical methods into the curriculum but also details the course timeline, assessment methods, peer evaluation, and analysis of students' performance in planning research projects. This suggests that combining hands-on projects with structured peer evaluations could offer a more comprehensive educational experience.

Meireles et al. [14] describe an experience report on using active learning in ESE Education, where they collected student feedback. Although the authors used a different study protocol, some of their results corroborate our results. For example, they concluded that active learning principles provide advantages in ESE education.

Usage of checklists in software engineering education. The studies by Cupryk (2022)[1], Petersen (2021) [16], and Molléri (2018) [15] explore using checklists in software engineering education to enhance students' critical appraisal skills in empirical research. Cupryk's study [1] finds that Empirical Standards Checklists benefit novice researchers, particularly in reviewing empirical papers, but suggests their effectiveness could be improved with additional support. Petersen and Molléri [16] evaluate a checklist's utility for assessing survey studies, finding student assessments consistent but less accurate compared to experts. Molléri et al. [15] confirm the educational value of checklists but note challenges with data analysis items. All three studies highlight that while checklists are valuable, their effectiveness is maximized when supplemented with thorough reporting, clear guidelines, and interactive discussions, aligning well with the comprehensive methodological approach discussed in our work.

Experience reports on the empirical methods teaching. The papers of Kuhrmann and Münch [12] and Luz, Oliveira, and Steinmacher [13] aim to improve software engineering education through experimentation. Kuhrmann and Münch focus on integrating small- and medium-sized experiments into courses to provide practical, hands-on experience, enhancing students' understanding of real-world phenomena in software engineering. Luz, Oliveira, and Steinmacher conducted a survey to understand how experimentation is taught across various institutions, emphasizing the need for a standardized approach and proposing a research agenda to enhance pedagogy. Both works underscore the value of practical, hands-on learning but approach it from different angles—one through detailed case studies and guidelines and the other through a comprehensive survey and strategic research agenda.

Iwazaki et al. [10] assess the benefits and challenges of teaching Systematic Literature Review (SLR) to graduate students, highlighting improved research skills and understanding of research topics, alongside challenges such as students' lack of prior knowledge and the complexity of the SLR process. These articles offer valuable insights into different pedagogical strategies for teaching empirical software engineering, each contributing to a comprehensive understanding of effective teaching methods and their impacts on student learning. Integrating their insights and our experience report can help create a robust framework for teaching empirical software engineering.

Improvement of competencies in educational settings. The articles of Santos, Vilela, and Vasconcelos [3] and Vilela and Lopes [20] both focus on improving competencies in educational settings through different methods. Santos, Vilela, and Vasconcelos employ Problem-Based Learning (PBL) to integrate multidisciplinary content and real-world problem-solving. Vilela and Lopes evaluate using an educational game, "Translation Loss," to improve requirements elicitation and communication skills. Both studies emphasize hands-on, experiential learning to enhance professional skills but differ in their approaches—PBL integrates broader interdisciplinary teamwork and problem-solving. At the same time, the game focuses on specific technical skills within a structured, game-based environment. These hands-on and experiential learning approaches are also used in our work as a methodological approach.

3 METHODOLOGICAL APPROACH

The context of this paper is an in-person scientific research methods course focused on ESE methods conducted in Portuguese, offered in the eighth semester of a Bachelor of Information Systems. The course was 60 hours (total) distributed in 36 one-hour and 40-minute weekly classes over a semester, as presented in Table 1. No additional tutor was available; only the professor would teach and grade all classes and assignments.

3.1 Intended learning outcomes

The intended learning outcomes included several aspects:

- **Understanding of Fundamental Concepts of Scientific Research:** Empower students to comprehend and apply basic and advanced concepts of scientific research, including the nature and purposes of scientific research.
- **Development of Research Planning Skills:** Teach students how to plan a research project, from setting goals to choosing appropriate data collection and analysis methods.
- **Proficiency in Specific Empirical Methods:** Provide theoretical knowledge about different empirical methods such as surveys, controlled experiments, case studies, systematic literature reviews and action research, and when each is appropriate.
- **Development of Skills in Scientific Writing:** Teach students to write research proposals and scientific papers.
- **Preparation for Academic Presentations:** Prepare students to present their research projects, developing oral and visual communication skills.
- **Skills in Critical Evaluation:** Develop the ability to critically assess peers' research work, using objective and constructive improvement criteria.

3.2 Students' Profile

This study was conducted with 17 undergraduate students without experience in scientific methods or ESE. The activities were performed individually except for the research fundamentals and empirical methods seminars described in Section 3.4.

3.3 Evaluation Method

The methodological approach involved conducting theoretical classes, partial deliveries of the research project, presentation of a research project, seminars on research fundamentals and empirical methods, evaluation activities of empirical articles, and peer research project evaluation. In the next sections, we describe the adopted timeline.

Each student presented 2 seminars, and the grading scheme adopted was: Research Project (30%) + Project Presentation (10%) + Partial Deliveries (15%) + Seminars (20%) + Evaluation Activities of research articles (10%) + Peer Research Project Evaluation (15%).

3.4 Course Timeline

We adopted the timeline described in Table 1 in the course.

Table 1: Summary of Course Outline.

Classes	Topics	Activities
1-5	Course Presentation, Fundamentals of Scientific Research, Overview of Empirical Research Methods	Practical activities
6-11	How to Read a Paper, The Literature Review, From Topics to Questions, From Questions to Problems, From Problems to Sources, Writing the Senior Thesis, Introductions and Conclusions, Scientific Paper Writing, Communicating Evidence Visually, Plagiarism and Ethics, and Planning e Drafting Your Report	Seminars, Practical activities
12-26	Systematic literature review, Survey, Questionnaire Surveys/Case Survey/Qualitative Surveys, Controlled Experiments, Case studies, Quantitative Simulation, and Action Research	Seminars, Evaluation of articles, Practical activities
27-36	Elaboration of research project	Elaboration of research project and presentation, Peer evaluation of the research project, and final delivery of the project.

[Classes 1-5]: The first classes involved the conduction of theoretical classes regarding the Course presentation (content, rules, and assessment aspects), Fundamentals of Scientific Research, Requirement Levels of Senior Thesis[1], Master thesis and Doctoral Thesis, Overview of empirical research methods, and practical Research Project Planning activities.

Classes were divided into seminars and practical activities to promote active and student-centered learning. Instead of mere receivers of information, students become active participants, allowing them to familiarize themselves with scientific research concepts more practically and collaboratively. This approach is supported by Dale's Cone of Learning theory, which suggests that students retain 90% of what they say and do after two weeks, compared to only 10% of what they read.

[Classes 6-11]: The first cycle of seminars was conducted. Through active and student-centered learning, the seminars aimed to help students become familiar with scientific research concepts. The students formed the teams by convenience, and the groups had different sizes and topics, as described in Table 2. We also had some practical classes to continue writing the research project during this period.

[Classes 12-26]: The second cycle of seminars was conducted. This one aimed to help students become familiar with the main empirical research methods. The students formed the teams by convenience, and the groups had different sizes and topics, as described in Table 3.

The seminars were divided so that the students presented one seminar listed in Table 2 in classes 6-11 and one seminar from Table 3 in classes 12-26. The topic selection was made by the students themselves.

Before conducting each second seminar, the students performed an activity to evaluate an article of their choice related to the topic of their research project that employed the method that would be presented in the seminar. The purpose of these activities was to let all students know the method that would be explained before

[1]Senior Thesis or Capstone Project is a term used at some universities in the United States to refer to an extensive research work or project that undergraduate students complete at the end of their courses. This work usually involves original research or a detailed analysis of a specific topic.

Table 2: Topics, material suggested, number of students per seminar, and its duration.

#	Topic	Material Suggestion	# students	Duration (min)
1	How to Read a Paper	Article: How to Read a Paper	3	40
		Article: How to Read a Scientific Research Paper		
		Article: Art of reading a journal article: Methodically and effectively		
2	The Literature Review	Book Research Methodology for Computer Science (book in portuguese - Section 3.2)	2	30
3	From Topics to Questions	Book The Craft of Research (Chapter3)	2	30
4	From Questions to Problems	Book The Craft of Research (Chapter4)	3	40
5	From Problems to Sources	Book The Craft of Research (Chapter5)	2	30
6	Writing the Senior Thesis	Book Research Methodology for Computer Science in portuguese (Chapter5)	2	30
	Introductions and Conclusions	Book The Craft of Research (Chapter14)		
7	Scientific Paper Writing	Book Research Methodology for Computer Science in portuguese (Chapter6)	2	30
	Communicating Evidence Visually	Book The Craft of Research (Chapter15)		
9	Plagiarism and Ethics	Book Research Methodology for Computer Science in portuguese (Chapter7)	2	30
		Book Research Methods (Section 5.2)		
		Book The Craft of Research (Part 5 - Section The Ethics of Research)		
10	Planning and Drafting Your Report	Book The Craft of Research (Chapters 12 and 13)	1	20

Table 3: Topics, material suggested, number of students per seminar and its duration.

#	Topic	# students	Duration
11	Systematic literature review	5	1h e 30 min
12	Survey	4	1h e 30 min
13	Questionnaire Surveys, Case Survey, Qualitative Surveys	4	1h e 30 min
14	Controlled Experiments	3	1h e 30 min
15	Case studies	5	1h e 30 min

the seminar so they could have questions to ask and promote a discussion during the presentation.

To support this activity, we prepared spreadsheets with questions for each method so the students could read the article and answer the questions regarding the methodological aspects of the article. An overview of the questionnaire used to evaluate a systematic literature review is presented in Figure 1 (in Portuguese).

[Classes 27-36]: The final classes were dedicated to the students writing the Research Project. Then, the students had classes to conduct the peer research project evaluation. The allocation of student reviewers to the projects was done by the professor considering the topics of the research projects so that a student would review a project from a related area.

To make this evaluation objective, we developed a checklist in which the students marked whether the criterion was fully, partially, or not met. This checklist, presented in Table 4, was implemented in a spreadsheet and made available to each student. They had to evaluate the project assigned to them, and when a criterion was answered, the Research Project Grade was automatically calculated.

The selection of the criteria presented on this checklist was based on reference criteria for evaluating an Undergrad Final Project proposed by Pinheiro and Bezerra [17] and evaluation criteria of the research committee used to evaluate research projects [4]. In this checklist, the highest possible score is 8 points.

After the assessments, the professor made the responses available to the projects' authors so that they could adjust their research projects.

It is important to highlight that the main result of this course was a research project containing context, motivation, research questions, goals, related work, and research methodology. To elaborate their projects, they should know the minimal aspects of the most used empirical methods to plan their research. Hence, we did not address the teaching of data analysis and interpretation of results since these topics are very complex and depend on the empirical method used.

Finally, the students presented their projects in 10 minutes and received suggestions for improvement from the professor and peers, which could be incorporated into the final version submitted for grading.

4 RESEARCH DESIGN

The following section outlines research questions, data collection, and data analysis procedures.

4.1 Research Questions

The following research questions guided the execution of this study:

RQ1: How did the students evaluate the course? We analyzed the students' perceptions of the course regarding seven aspects: Approach to the Topic, Content References Provided, Clarity Regarding Course Objectives, Achievement of Objectives, Contribution to their Education, Development of Critical Ability, and Overall Evaluation of the Course.

RQ2: What is the degree of easiness and usefulness of the learning activities from the viewpoint of the students? We gathered feedback from students on their opinions about the ease of use and their perceptions of the usefulness of the learning activities conducted in the course: Partial Deliveries of Project Activities, Project Conducted During Classes, Seminars on Research Methods, Evaluation Activities of Articles on Each Research Method, Development of the Research Project, Evaluation of a Peer's Research Project, Presentation of the Research Project.

RQ3: What are the positive aspects and improvements of the methodological approach? To address this question, we conduct a thematic analysis of the feedback questionnaire to qualitatively assess the extent to which students found the approach effective.

RQ4: What is the distribution of peer evaluation scores for research projects in the course? We collected and analyzed peer evaluation scores in the course, categorizing them into percentage ranges to assess performance distribution. The scores were then visualized using a bar chart highlighting the number of students in each range.

4.2 Data Collection and Analysis Procedures

To gather data to address research questions RQ1, RQ2, and RQ3, we requested that the students answer a **feedback questionnaire**. The students assessed the usefulness and ease of the approach and

A	B
Information about the Final Project (TCC)	
Research Theme/Topic:	
Research Objectives:	
Research Questions:	
Chosen Article	
Motivation/Justification:	
Article Title:	
Link:	
Methodology	
Central Research Question:	
Secondary Questions:	
Keywords:	
Synonyms for Keywords:	
Search String:	
Research Sources Used:	
Number of Articles Returned:	
Exclusion Criteria:	
Inclusion Criteria:	
Article Selection Procedures:	
Quality Criteria:	
How were the criteria applied?	
Number of articles selected per database:	
Critical Analysis of the Article	
How was the data analysis conducted?	
How are the responses presented in the article?	
What are the main conclusions of the article?	
How can the chosen systematic review contribute to the TCC?	

Figure 1: Questionnaire used to evaluate systematic literature review articles

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Table 4: Aspects and Criteria used to the peer research project evaluation.

ID	Aspects	Evaluation Criteria	Satisfied?	Score	Comments on the Criterion
ID1	Title	Does the title clearly state what will be done and what is its field of application?	NO	0.5	
ID2	Introduction	Who is the project for? Target audience the work is aimed at. Ex: developers, managers, or users.	NO	0.5	
ID3		Why does the project exist? What is the relevance of the project to the target audience? (justification in the present)	NO	0.5	
ID4		What does the project contribute to? Project impact: the expected positive and lasting transformations. (consequences in the medium/long term)	NO	0.5	
ID5		Does it discuss the importance of conducting the research for science and society using citations from the literature review and coherent arguments with the study proposal?	NO	0.5	
ID6	Objectives	Is the general objective clearly formulated? Is it coherent with the project title?	NO	0.5	
ID7		Are the specific objectives clearly defined and do they contribute to the achievement of the general objective?	NO	0.5	
ID8	Related Work	Are works with related objectives discussed?	NO	0.5	
ID9		Is a comparison between related works presented?	NO	0.5	
ID10	Methodology	Is it coherent with the general and specific objectives?	NO	0.5	
ID11		Are the steps/phases of conducting the research well presented, so that a non-expert reader can imagine executing them?	NO	0.5	
ID12		Does it briefly describe the methods that will be used?	NO	0.5	
ID13		Does it detail the data analysis process? Is the analysis process coherent with the nature of the research?	NO	0.5	
ID14	Internal Coherence	Is there coherence between the parts of the text: objectives and methodological procedures?	NO	0.5	
ID15	Formatting and Overall Text	Is the text well formatted, presented, and in clear and correct language?	NO	0.5	
ID16	References	Does it present current and appropriate bibliography on the research topic?	NO	0.5	
Research Project Grade:				**8**	

provided comments on their experience. The scales used in the feedback questionnaire were the same as those employed by Ferrari et al. [8] and by our previous works [21] [19].

For usefulness, the scale ranged from Extremely useful (5) to Not at all useful (1). For easiness, the scale ranged from Extremely difficult (5) to Not difficult at all (1). Additionally, the students were asked to comment on the effectiveness of their experience and suggest improvements. The students evaluate the approach's usefulness and ease and comment on their experience.

To answer RQ4, we analyzed the students' grades in the peer evaluation activity.

5 RESULTS

11 of the 17 students answered the feedback questionnaire since it was optional. The results are discussed in the next sections.

5.1 RQ1: How did the students evaluate the course?

We analyzed the students' perceptions of the course regarding seven aspects: Approach to the Topic, Content References Provided, Clarity Regarding Course Objectives, Achievement of Objectives, Contribution to their Education, Development of Critical Ability, and Overall Evaluation of the Course. The students chose an option where 1 was unsatisfactory, and 5 was excellent, and each category's results are presented in Figure 2.

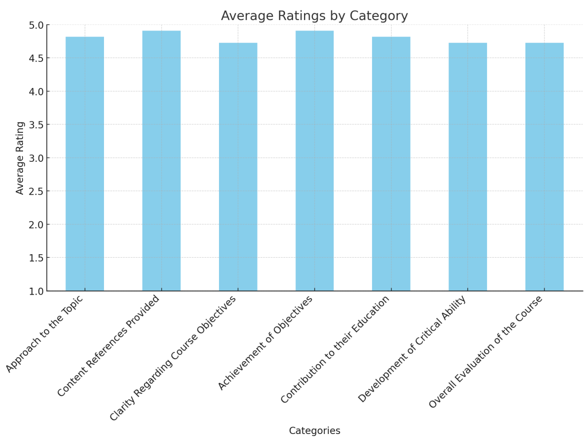

Figure 2: Students evaluation of the course

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The data suggests a well-received course with some specific areas that can be adjusted to maximize satisfaction and teaching effectiveness. As strengths of the course, we can highlight:

- **High Overall Satisfaction:** The ratings across most categories are high, generally around 5 (the maximum). This suggests a high level of satisfaction with the course among the participants.
- **Approach to the Topic**: Consistently rated with 5, showing that students are very satisfied with how the topic was addressed.
- **Meeting Objectives:** The high rating suggests that the course meets its expected objectives.
- **Provided Content References:** Also consistently high, indicating that the support materials are adequate and useful.
- **Impact on Training and Development:** The ratings for "Contribution to Training" and "Development of Critical Capacity" were also high, which implies that the course is effective not only in delivering knowledge but also in enhancing the critical thinking abilities of the students.

Answer to RQ1: *Students generally evaluated the course positively, highlighting its flexibility, practical learning approach, and thorough preparation for final projects. High satisfaction was noted in areas such as the approach to the topic, content references provided, and the achievement of objectives. However, areas for improvement included the clarity of course objectives and the development of critical thinking skills.*

5.2 RQ2: What is the degree of easiness and usefulness of the learning activities from the viewpoint of the students?

We gathered feedback from students on their opinions about the ease of use and their perceptions of the usefulness of the learning activities conducted in the course: Partial Deliveries of Project Activities, Project Conducted During Classes, Seminars on Research Methods, Evaluation Activities of Articles on Each Research Method, Development of the Research Project, Evaluation of a Peer's Research Project, Presentation of the Research Project.

The stacked bar chart of Figure 3 displays the distribution of responses regarding the usefulness of various tasks performed during the course.

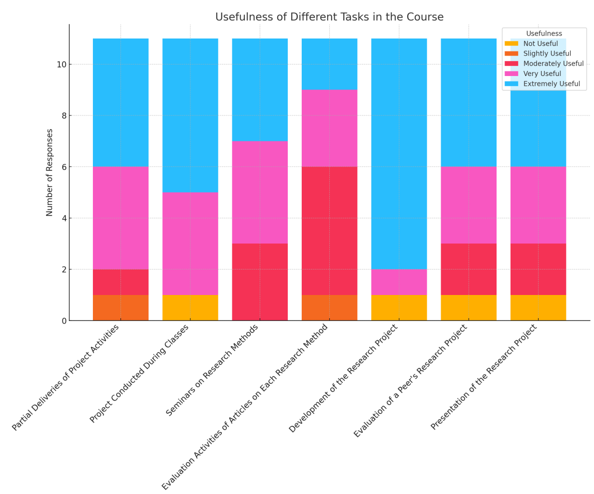

Figure 3: Usefulness of the activities.

The students' answers suggest that **most of the course activities are viewed as extremely useful by the students**. Activities such as "Partial submissions of project activities," "Project carried out during classes," "Seminars on research methods," "Preparation of the research project," "Evaluation of a colleague's research project," and "Presentation of the research project" predominantly received ratings of "Extremely Useful" or "Very Useful." This indicates that students consider these activities highly beneficial for their learning.

The stacked bar chart of Figure 4 shows the **difficulty of various activities** within the course and provides a clear visual representation of how students perceive the challenges associated with each activity.

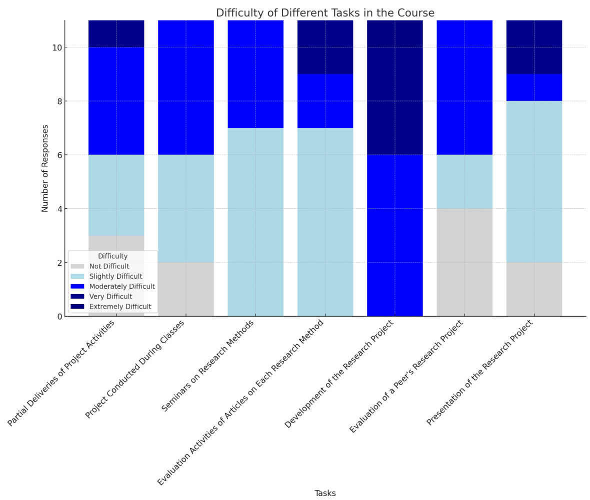

Figure 4: Difficulty in conducting the activities.

The **Most Challenging Tasks** were the "Development of the Research Project" and "Evaluation Activities of Articles on Each Research Method" since they consistently show higher proportions of "Very Difficult" and "Extremely Difficult" responses. This suggests that these tasks are perceived as more challenging, possibly due to the complexity of the work involved or the higher cognitive demands these activities require.

The **Least Challenging Tasks** were the "Evaluation of a Peer's Research Project" and "Presentation of the Research Project" since they had significant responses in the "Not Difficult" and "Slightly Difficult" categories. These activities might be relatively less demanding or may align better with students' existing competencies.

Finally, the **Activities with Moderate Difficulty** were "Partial Deliveries of Project Activities" and "Project Conducted During Classes" since they show a notable number of responses in the "Moderately Difficult" category. These tasks are likely seen as challenging but manageable, which could indicate effective learning challenges that promote growth without overwhelming students.

5.3 RQ3: What are the positive aspects and improvements of the methodological approach?

To answer RQ3, we analyzed the answers to the feedback questionnaire about positive aspects and points of improvement by performing a thematic analysis similar to the one presented in the paper of Ferrari *et al.* [9] and our previous work [21]. The themes were grouped into Positive aspects and Points of Improvement presented in Table 5.

Answer to RQ2: *Most students found the course activities to be highly useful, particularly the partial submissions of project activities, seminars on research methods, and the development and presentation of the research project. However, some activities, like the evaluation of articles, were seen as challenging.*

Table 5: Thematic analysis of the positive aspects and areas for improvement.

Main Theme	Subthemes	Count
Positive Points		
Flexibility and Accessibility	Days without classes, Remote presentations, Distance functionality	4
Preparation for Final Project (TCC)	Early start on final project, Idea validation, Topic selection	2
Practical Learning of Research Methods	Research project development, Research methods, Evaluation of projects and articles	3
Knowledge of Various Research Methods	Variety of methods, Understanding methods, Course structure	2
Points of improvements		
Project Topic Selection	Early topic selection, Idea development	2
Clarity of Course Requirements	Understanding of project requirement, Clear communication	1
Pacing of Activities and Deliverables	Number of deliverables, Activity spacing	4
Seminar and Presentation Structure	Length of presentations, Focus on key points	1
Difficulty in Finding Articles	Article search, Detailed explanation of methods	1
Time Constraints	Learning multiple methods in short time	1

The thematic analysis of student feedback for the scientific research methods course highlights significant strengths and areas for improvement. The course structure facilitated early engagement with research concepts and project planning, which helped students validate their ideas and select suitable topics for their final projects, building their confidence and competence in research skills.

Practical learning of research methods was another feature, as students valued the hands-on approach to developing research projects and evaluating peer work. This practical engagement increased their understanding of various empirical methods and improved their ability to apply them in real-world scenarios. However, some areas for improvement were identified, including the early selection of research project topics, which students found challenging. They suggested an initial exploratory phase with the professor's guidance to help develop more mature research topics. Additionally, clearer communication of course requirements and a more balanced pacing of activities and deliverables were recommended to alleviate pressure and enhance the learning process.

Therefore, we obtained some evidence that the course provided a significant opportunity for professional growth. However, specific areas could be enhanced to ensure an even more effective learning experience for future students.

Answer to RQ3: *The thematic analysis identified several positive aspects, such as flexibility, practical learning, and comprehensive exposure to various research methods. However, areas for improvement included early selection of project topics, clearer communication of course requirements, and a more balanced pacing of activities and deliverables. Enhancing support for finding relevant articles and understanding complex methodologies was also suggested.*

5.4 RQ4: What is the distribution of peer evaluation scores for research projects in the course?

Considering that **the main result of the scientific research methods course was a research project**, we analyzed the students' grades in the peer evaluation of the research project. The table below presents the peer evaluation scores for a research project in the course, along with the corresponding percentages. The maximum possible score for the evaluation was 8. The scores and percentages highlight each student's performance, clearly understanding their achievements.

Figure 5 presents a bar chart that shows the distribution of peer evaluation percentages among the students. The chart categorizes the students' grades into four percentage ranges: 65.63% - 81.25%, 81.26% - 87.50%, 87.51% - 93.75%, and 93.76% - 100%. Each bar represents the number of students (y-axis) within each percentage range (x-axis), clearly representing their performance.

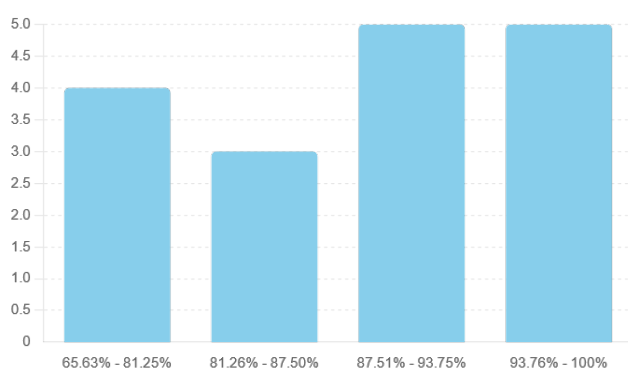

Figure 5: Distribution of Peer Evaluation Percentages.

The corresponding grades range from 65.63% to 100%, indicating a wide range of performance levels among the students. Most students scored percentages above 87.50%, with nine students in the 87.51% to 93.75% range and four students in the 93.76% to 100% range, showing that most students performed quite well in their peer evaluations.

A few students had percentages ranging from 65.63% to 81.25%, with three students in this range, suggesting that while these students met the basic requirements, there may be areas for improvement in their research projects. One student had a percentage in the 81.26% to 87.50% range, indicating solid performance but also room for growth.

Overall, the data indicates a strong performance by the majority of the students, reflecting well on the effectiveness of the course in preparing students to conduct and present their research projects. This indicates that the course effectively facilitated a deep understanding and practical application of empirical research methods.

Aiming to understand the most common errors found in the peer evaluation, we counted the number of errors reported by the peers. Table 6 summarizes the frequency of errors identified in evaluation criteria for research projects described in Table 4. The errors were counted when a criterion was marked as "No" or "Partially" satisfied across the peer evaluations from the students' answers.

Table 6: The number of times each criterion was marked as not or partially satisfied (# errors).

ID	Aspects	Evaluation Criteria	Number of Errors
ID1	Title	Does the title clearly state what will be done and what is its field of application?	11
ID2	Introduction	Who is the project for? Target audience the work is aimed at. Ex: developers, managers, or users.	6
ID3		Why does the project exist? What is the relevance of the project to the target audience? (justification in the present)	8
ID4		What does the project contribute to? Project impact: the expected positive and lasting transformations. (consequences in the medium/long term)	5
ID5		Does it discuss the importance of conducting the research for science and society using citations from the literature review and coherent arguments with the study proposal?	7
ID6	Objectives	Is the general objective clearly formulated? Is it coherent with the project title?	8
ID7		Are the specific objectives clearly defined and do they contribute to the achievement of the general objective?	8
ID8	Related Work	Are works with related objectives discussed?	11
ID9		Is a comparison between related works presented?	12
ID10	Methodology	Is it coherent with the general and specific objectives?	7
ID11		Are the steps/phases of conducting the research well presented, so that a non-expert reader can imagine executing them?	9
ID12		Does it briefly describe the methods that will be used?	6
ID13		Does it detail the data analysis process? Is the analysis process coherent with the nature of the research?	11
ID14	Internal Coherence	Is there coherence between the parts of the text: objectives and methodological procedures?	9
ID15	Formatting and Overall Text	Is the text well formatted, presented, and in clear and correct language?	7
ID16	References	Does it present current and appropriate bibliography on the research topic?	6

Figure 6 presents the number of errors versus ID for a visual comparison. This figure provides insightful data on where students faced the most challenges in their research projects. The criteria with the highest number of errors were *"Is a comparison between related works presented?"* (ID9) with 12 errors. We also observed several criteria with 11 errors: "*Are works with related objectives discussed?"* (ID8),*the discussion of the data analysis process* (ID13), *Does the title clearly state what will be done and what is its field of application?* (ID1).

These high-error areas highlight significant gaps in students' abilities to compare related works critically, clearly state their project's scope and objectives, and adequately detail their data analysis processes. These findings suggest that additional instructional support

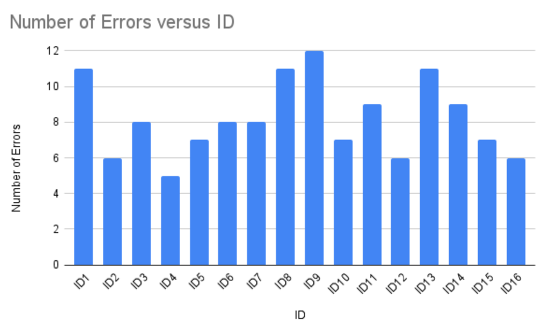

Figure 6: Number of errors versus ID.

is necessary in these areas. For example, incorporating more examples and exercises that focus on comparing related works, formulating precise research titles, and detailing data analysis processes can help students improve their research project quality.

The high number of errors in criteria ID11 and ID14, with 9 errors, indicates that students struggled significantly with presenting their research steps clearly and maintaining coherence between their objectives and methodologies. These challenges suggest a need for enhanced instructional focus on writing detailed methodology sections and ensuring logical flow within research projects. Addressing these issues through step-by-step guides, in-depth examples, workshops, and peer review sessions could help students improve their research work's clarity, structure, and coherence.

The criteria with the fewest errors were ID2, ID4, ID12, and ID16, each with 6 errors. These criteria focus on identifying the target audience (ID2), discussing the impact of the project (ID4), briefly describing the methods used (ID12), and presenting appropriate references (ID16). The fewer errors in these areas suggest that students were relatively successful in articulating the project's relevance, identifying their audience, providing a concise overview of their methods, and citing current and appropriate literature.

In summary, this analysis underscores specific areas that require additional focus and support, particularly in discussing related works, formulating clear titles, detailing methodologies, and ensuring internal coherence. Addressing these issues through targeted workshops, clearer guidelines, and more examples could significantly improve the quality of students' research projects.

Answer to RQ4: *The peer evaluation scores ranged from 65.63% to 100%, with most students scoring above 87.50%. This distribution indicates strong overall performance but highlights areas where some students struggled. Furthermore, the analysis of common errors revealed that students particularly faced challenges in comparing related works, formulating clear research titles, detailing methodologies, and maintaining internal coherence.*

5.5 Lessons Learned

The feedback of the students allowed us to detect the need to improve the course in some areas. The main learnings from teaching this course include the following:

- We identified **Clarity of Course Objectives** as an area for improvement due to one rating of 3, suggesting occasional confusion or lack of clear communication. However, the overall average rating was good, indicating that most students found the objectives clear. The lower rating might be from a student who missed the first classes, where objectives are presented, but this is speculative due to anonymous feedback. We recommend refining how objectives are presented and reiterated throughout the course to enhance clarity. Addressing this will help ensure all students understand the course goals. We suggest starting each activity with a brief explanatory session on its objectives and benefits to improve the perception of usefulness.
- **the "Article Evaluation Activities" received varied feedback**, suggesting reviewing how these activities are implemented may be useful and improving the explanation of their importance and relevance for developing critical skills.
- **Students also highlighted the need for shorter, more focused seminar presentations and better support in finding relevant articles for specific research methods**. Addressing these challenges could include dedicated sessions on research strategies and curated lists of recommended readings.
- **Development of Critical Thinking:** despite including activities such as evaluating scientific articles with different empirical methods and assessing peers' research projects, some students might not have understood the importance and benefits of these exercises. To address this, we suggest clearly explaining the objectives and value of these activities, incorporating guided reflection classes focused on critical thinking strategies.
- **Engagement in Practical Activities:** We observed that practical activities, such as evaluating scientific articles and conducting research projects, are highly valued by students and significantly contribute to learning.
- **Importance of Feedback and Reflection:** incorporating reflection sessions after completing each activity can help students better understand and apply what they have learned. More interactive and personalized feedback sessions can help clarify doubts and increase student engagement.
- **Integration of Theory and Practice:** Combining theoretical classes with practical activities is essential for developing students' research skills.
- **Emphasize the analysis of related work.** This section was one of the points where students made the most mistakes. This aspect must be better discussed in the course.

As expected, the students related their difficulty in developing their research projects. Addressing the lessons learned above could help to reduce this difficulty. We found some areas of the course that can be improved in future editions of the discipline:

- Clarity of Objectives: There is a need to reiterate the course objectives more clearly throughout the lessons.

- Complexity of Activities: Some activities were considered challenging, suggesting that additional support or more detailed explanations could be useful.
- Selection and Development of Topics: The difficulty in selecting and developing research topics from the beginning of the course suggests the need for an initial exploratory phase with closer guidance from the teacher.
- However, we believe their impact is limited since the students greatly understood the methods, when to apply them, and the differences between them.

6 CONCLUSIONS AND FUTURE WORKS

This paper presented an experience report of an undergraduate scientific research methods course focused on Empirical Software Engineering that adopted a comprehensive methodological approach. We discussed the students' perceptions regarding the positive aspects and points of improvement of the approach (RQ1), the degree of easiness and usefulness of the learning activities (RQ2), the positive aspects and improvements of the methodological approach (RQ3), and the distribution of peer evaluation scores for research projects (RQ4).

Although we have some areas to improve, we believe that peer reviewing and divided classes are possible innovations. The course successfully empowered the students with essential research skills and knowledge, reflected in the high peer evaluation scores. The course's strengths are its practical learning approach and thorough preparation for final projects. However, specific areas such as early selection of research project topics, clarity of course requirements, and pacing of deliverables posed challenges for some students. The need for better support to find relevant articles and understand complex methodologies was also evident. Addressing these issues can enhance the learning experience and better support students struggling with these aspects.

The analysis of student feedback revealed that the most useful techniques in the course were the partial submissions of project activities, seminars on research methods, and the development and presentation of the research project. Students consistently rated these activities as extremely useful or very useful. The partial submissions helped students stay on track with their projects, receive timely feedback, and make necessary adjustments throughout the course. Seminars on research methods provided in-depth knowledge and practical insights into various empirical techniques, enabling students to apply these methods effectively in their research. The development and presentation of the research project allowed students to integrate and demonstrate their learning comprehensively, reinforcing their understanding and enhancing their communication and presentation skills.

In terms of ease, students found that evaluating a peer's research project and presenting their research project were the least challenging activities. Most of the students rated these tasks as not difficult or slightly difficult. The peer evaluation process was straightforward and familiar, allowing students to apply their critical thinking skills in assessing the work of their colleagues. The presentation of their research project was also considered manageable, possibly because of the extensive preparation and practice provided throughout the course. These activities aligned well with the students' existing competencies, making them relatively easier to complete compared to other more demanding tasks, such as developing the research project or evaluating empirical articles.

As future work, we intend to:

- replicate this empirical study with a larger sample;
- incorporate dedicated sessions on research strategies and curated lists of recommended readings to aid in finding relevant articles;
- provide more in-depth sessions on the methodologies to help students better understand these topics;
- implement an initial exploratory phase for project topic selection, along with clearer communication of course requirements and a more balanced pacing of activities;
- explore the long-term impact of these adjustments on student performance and satisfaction.
- analyze the grades of students when they finish the TCC.

6.1 Threats to Validity

In the following, we evaluate the threats to validity using the classification framework provided by Wohlin *et al.* [22].

In addition to the ethical issues discussed below, a potential source of bias is that the study leader, the course instructor, and the article's first author are the same individual. However, we argue this threat is limited because the course results were based on students' research projects that were not supervised by the lead author. We adopted different mechanisms to grade the students.

To address *ethical issues*, it is impossible to associate students' opinions with their names; all information was analyzed anonymously. Additionally, students were not graded based on their feedback content or responses to the questionnaire.

Concerning *external validity*, we believe that our results apply in similar educational settings.

The questionnaire was designed with a Free and Informed Consent Form (TCLE), exempting approval from an Ethics Committee, as it falls into the category *Public opinion research with non-identifiable participants*, according to Circular Letter No. 17/2022 /CONEP/SECNS/MS, July 2022 and CIRCULAR LETTER No. 12/2023/ CONEP/SECNS/DGIP/SE/MS[2].

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ARTIFACT AVAILABILITY

This paper has no supplementary material.

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