Research Paper

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TEAM LEARNING IN FINNISH ENGINEERING CURRICULA: A DATA MINING APPROACH

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ABSTRACT

Teamwork is a critical skill in engineering practice, yet previous studies suggest that recently graduated engineers often lack sufficient collaboration and communication skills. Despite its importance, team learning is rarely addressed from a curriculum-level perspective in academic literature, and data mining methods are seldom used to analyze engineering curricula.

This study investigates how team learning is represented in the declared curricula of 18 Finnish Universities of Applied Sciences offering full-time Bachelor of Engineering programs starting in Fall 2024. A dataset of 9509 course descriptions was collected using a custom-built web crawler. After initial filtering with regular expressions, 2178 course descriptions were manually analyzed and categorized according to five criteria related to team learning, such as prerequisites, learning outcomes, assessment methods, learning activities, and project work.

The results reveal that team skills are explicitly listed as a learning outcome in 677 courses and as part of assessment in 369 courses. However, only six courses mention team skills as a prerequisite. Team learning methods are often vaguely

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described, and project work is frequently mentioned without clarification on whether it is team-based.

We argue that team learning should be treated as a curriculum-level competence that is intentionally developed throughout engineering studies. This study contributes a large-scale, data-driven perspective and lays the groundwork for further in-depth qualitative analysis.

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1 INTRODUCTION

1.1 The importance of team learning

Teams are defined as groups of individuals characterized by task interdependence and collective responsibility for outcomes (Cohen & Bailey, 1997). Central to team learning are processes such as collaborative knowledge construction, constructive conflict resolution, knowledge sharing and application, joint action and reflection, and boundary crossing (Decuyper et al., 2010). In the context of higher education, the use of teams as a pedagogical strategy is widespread, aimed at enhancing student learning experiences. Typically, larger student cohorts are subdivided into smaller, task-oriented groups. This pedagogical method aligns with socio-constructivist theories of learning, which underscore the critical role of social interactions in the co-construction of knowledge (Tynjälä, 1999).

Engineers spend a considerable amount of their working time collaborating and interacting with others (Flening et al., 2022; Passow & Passow, 2017). Alumni consistently identify teamwork as one of the most critical skills required in engineering practice (Passow, 2012).

Although teamwork skills are important, recent graduates may not fully meet the required standards. According to employers, newly graduated engineers often lack key interpersonal competencies, commonly referred to as soft skills, particularly in areas such as collaboration and communication (Czerwińska-Lubszczyk et al., 2022; Hirudayaraj et al., 2021; Thornhill-Miller et al., 2023). While the term *soft skills* is frequently used in both academic and professional discourse, it has also been critiqued for being vague and potentially diminishing the perceived value of these competencies. For instance, Berdanier (2022) argues for a “hard stop” to the term, advocating for more precise and respectful language when referring to essential human and professional capabilities. Nevertheless, the concept remains central to discussions on engineering education. Given the inherently collaborative nature of engineering work, it is essential to incorporate teamwork-related skills into engineering education (Johri et al., 2014).

Martin et al. (2005) state “*the implications for curriculum development are that the non-technical skills can not be taught in isolation from the technical context in which they will be used*”, which highlights the importance of systematically integrating team skills into engineering curricula.

1.2 Team learning in engineering curricula

Harden (2001) presents curriculum as three-fold: the declared curriculum (“what is assumed the students are learning”), the taught curriculum (“the curriculum that is presented”) and the learned curriculum (“what students actually learn”). In this study, the analysis is based on declared curriculum.

An ongoing systematic literature review on team learning in engineering education by the authors suggests that existing research typically approaches team learning at the individual course level, rather than as a systematic, curriculum-level pedagogical strategy. Out of the 83 analyzed articles, only a few explicitly address team learning from a curriculum-level perspective, whereas most studies focus solely on individual courses. This course-centric perspective may limit the understanding of team learning as a holistic educational approach, potentially weakening its effectiveness. There is a need for curriculum-level planning to ensure that team learning is purposefully embedded, systematically assessed, and developed throughout engineering programs.

Team learning is present in some frameworks for engineering curriculum design. For example, CDIO (conceive-design-implement-operate) statement of goals for engineering syllabus includes teamwork and collaboration (Malmqvist et al., 2022). On a more general note on curriculum design, Fung (2017, p. 126) values connection and collaboration between students “rather than filling up every corner of the curriculum with individual tasks”.

Systematic approaches have been taken to analyze engineering curricula. Graham (2018) provides an interview-based global state-of-the-art overview of engineering curricula. The report is based on 178 interviews conducted with representatives from current and emerging leading institutions in engineering education. The report highlights key forms of team learning, particularly in the context of emerging leader institutions. These include project-based learning, interdisciplinary teamwork, work-integrated projects, and structured opportunities for student reflection. In programs such as those at SUTD and UCL Engineering, team learning is not treated as an add-on but is embedded into the curriculum structure. This provides a useful contrast to curricula where teamwork is mentioned only as a peripheral element.

Complementing this, Garbin et al. (2022) use a capability maturity model to assess active learning methods. They present a high-level capability maturity model for assessing the integration of active learning across engineering programs instead of course-level curriculum mapping. The focus is on institutional practices and curriculum-wide implementation rather than detailed analysis of individual courses. Similarly, Mendoza et al. (2022) present a learning outcomes-based curriculum design framework that emphasizes coherence across macro (institutional), meso (program), and micro (course) levels. It introduces a structured assessment cycle to support continuous improvement, ensuring that program and course learning outcomes are systematically evaluated and aligned with educational goals. As an additional methodological contribution, Kovacs et al. (2024) present a Q-methodology approach for constructing curriculum skills profiles. Their method engages participants in sorting and reflecting on the relative importance of various engineering skills, enabling the identification of skill clusters and institutional or disciplinary profiles. This participatory technique offers a novel way to inform curriculum development by capturing subjective perspectives on skill relevance.

Although engineering curricula have been examined, and tools for examination developed in prior research, the topic remains relatively underexplored in relation to team learning. Despite its acknowledged significance, team learning is seldom addressed in curriculum analysis literature. Moreover, data mining has rarely been utilized as a methodological tool in this context. With our approach, we aim to contribute novel insights into how engineering curricula can be systematically analyzed and better understood.

1.3 Research questions

To understand the current situation in Finnish engineering education, two research questions were formed:

RQ1: How is team learning articulated in course descriptions across different years of study as part of the declared curriculum?

RQ2: How are team skills positioned in engineering course descriptions as part of the declared curriculum: as skills to be taught or assumed?

2 METHODOLOGY

2.1 Data collection

The data for this study consists of publicly available engineering curricula from 18 Finnish Universities of Applied Sciences. All full-time, four-year Bachelor of Engineering degree programs starting in Fall 2024 were included. Some universities also offer flexible, work-oriented study programs in addition to full-time studies. These flexible curricula were excluded from the analysis.

Data collection took place between March and April 2024. When available, Finnish versions of curricula and course descriptions were used. If a Finnish version was not accessible, the English version was selected. Some curricula were published in Swedish; in these cases, a corresponding version in Finnish or English was also available and used instead.

The data gathering process began with the construction of a database that models the curriculum structure of each institution. This database includes identifiers for the higher education institution (HEI), degree program, and course, as well as the course name and its assigned academic year.

To collect the actual course description texts, a custom web crawler was developed using Python and Selenium. As each HEI uses a different online curriculum system, several crawler versions were implemented. The crawler downloaded the relevant section of each course description as a text file, using the database identifier as the file name.

Once the download process was completed, the integrity of the data was verified: each text file was matched to a database entry, and vice versa.

In total, 9509 course descriptions were downloaded, representing 6095 unique courses. Before conducting detailed analysis, an initial filtering was performed using regular expressions, as shown in Table 1.

Table 1. Regular expression for initial filtering

```
(tiimi|ryhm|ongelmaläht|ongelmaperust|yhteis|vertais|projekti|team|
group|pbl|problem[-\s]based|co[-]*oper|collab|peer|project)
```

After the initial filtering, 2178 course descriptions remained. The filtering was intentionally designed to maximize recall, ensuring that all potentially relevant results would be retained for further analysis. Therefore, the method avoids false negatives. The regular expression used for filtering was intentionally broad, which results in false positives. For instance, a course description that includes the word *steam boiler* will be selected due to the substring *team*. The regular expression includes both Finnish and English terms to accommodate the multilingual nature of the data.

2.2 Analysis

Five criteria were developed to support the categorization of data for statistical analysis. Each course in the filtered dataset (n = 2178) was manually tagged by the first author according to the criteria defined in Table 2.

Table 2. Definition of team learning criteria

Criterion	*Definition of the criterion*
C1	Team skills as a prerequisite for the course
C2	Team skills as a learning outcome of the course
C3	Team skills as assessment criteria of the course
C4	Team learning defined as a learning method in the course
C5	Some form of project work included in the course description

To facilitate the categorization process, a simple custom tool was developed (see Figure 1). The tool used the regular expressions listed in Table 1 to highlight relevant keywords in each course description. Courses were categorized using keyboard shortcuts (1–5) corresponding to the criteria. Once the tagging process was complete, the tool generated a JSON file containing the classification data.

This JSON file was then combined with the original curriculum database to compile the dataset for final analysis. The resulting dataset includes information on all 9509 course descriptions (6095 unique courses). Of these, 1035 courses were identified as meeting one or more of the criteria listed in Table 2. The majority of the courses did not include any explicit reference to team learning according to these criteria.

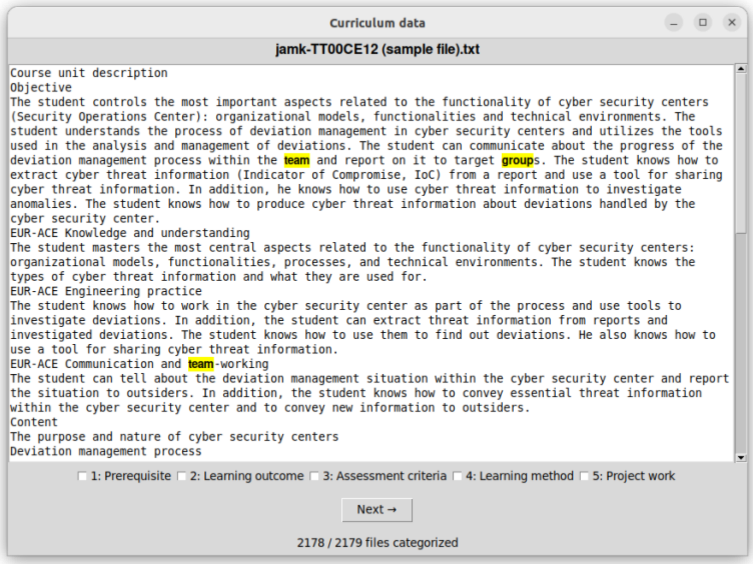

Fig 1. Tool used to categorize the course data

2.3 Curriculum map

The final dataset is organized as a large curriculum map (e.g. Bester & Scholtz, 2012; Harden, 2001), a simplified excerpt of which is shown in Table 3.

Table 3. Simplified example of a curriculum map

HEI	*Course name*	*Academic year*	*Criteria 1*	*Criteria 2*	*…*
HEI-1	Course 1	1		X	
HEI-1	Course 2	4	X		
	…				
HEI-18	Course 9509	2		X	

3 RESULTS

The key results of the study are compiled in Table 4, which presents the distribution of courses meeting the defined team learning criteria across the different academic years. The total number of courses included in the study is 9509.

Table 4. Occurrence of team learning criteria across different study years.

Criterion	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Total*
C1	-	3	3	-	6
C2	257	146	190	84	677
C3	106	109	112	42	369
C4	128	142	141	41	452
C5	205	232	307	106	850
Total	696	632	753	273	

The ECTS credits for courses vary from 1 to 30, while median being 5.

An alternative perspective on the findings involves examining the distribution of course units based on the number of criteria they fulfill, ranging from none to all five.

This analysis shows that it is relatively rare for course units to meet several of the criteria at once, while it is quite common for none of the criteria to be present. The results are shown in Table 5 below.

Table 5. Occurrence of team learning criteria across courses.

Number of criteria present	*Number of courses*
0	8 072
1	1 075
2	276
3	71
4	15
5	0

3.1 Team learning across different years of study

The first research question *How is team learning articulated in course descriptions across different years of study as part of the declared curriculum?* is answered by the data shown in Table 4. Team learning criteria are less common in the fourth year, which can be explained by the focus on the final thesis rather than coursework. Apart from this, the prevalence of team learning remains relatively consistent across the earlier years of study.

3.2 Teaching and utilizing team learning

We approach the second research question *How are team skills positioned in engineering course descriptions as part of the declared curriculum: as skills to be taught or assumed?* by analyzing the team learning criteria across courses in Table 4.

Team skills are positioned in engineering course descriptions both as assumed and as taught, but with a clear emphasis on the latter being relatively limited. The most striking finding concerns C1 (*team skills as a prerequisite for the course*). Out of the total 9509 courses, only six explicitly state team skills as a prerequisite. However, it is possible that in some cases the prerequisite is a specific course that includes team learning in its content. In such instances, team skills may be implicitly required, even if not explicitly stated as a prerequisite in the course description. The prerequisites are typically described in general terms, such as “ability to work in a group” or “ability to work both in a team and independently”.

On the other hand, team skills are defined as a learning outcome in 677 courses, indicating that they are more often positioned as skills to be taught. However, they appear in the assessment criteria of only 369 courses, suggesting a gap between intended learning outcomes and actual evaluation practices.

Some form of team learning method was mentioned in 452 courses. In most cases, this was limited to a general reference such as *group work*, with more specific approaches like *problem-based learning* mentioned only rarely.

Projects were referenced in 850 courses, but the descriptions often lack detail, making it unclear whether the project work is conducted individually or in teams. This further complicates the interpretation of how team skills are integrated into the curriculum.

Table 5 shows that it is rare for a course to meet more than three of the criteria (Table 2) listed in the course descriptions. None of the courses included all five criteria.

In summary, while team skills are occasionally assumed, they are more commonly positioned as skills to be taught, though often without clear alignment between learning outcomes, teaching methods, and assessment.

4 DISCUSSION AND CONCLUSIONS

This study examined how team learning is represented in the declared curriculum of Finnish engineering education. The dataset consisted of 9509 course descriptions from full-time, four-year Bachelor of Engineering programs, offered by 18 Finnish Universities of Applied Sciences.

The analysis focused on the declared curriculum, defined by Harden (2001) as what is assumed students are learning, based on course descriptions and learning objectives. Two research questions guided the study: (1) how team learning is articulated across different years of study, and (2) whether team skills are positioned as competencies to be taught or assumed.

The findings show that team learning is present throughout the curriculum, with relatively consistent representation across the first three years of study. Team skills are rarely stated as prerequisites in course descriptions. Instead, they are more often presented as learning outcomes. However, this is not always supported by clear assessment criteria or detailed descriptions of how the skills are taught.

4.1 Future research

In future research, we recommend conducting a more detailed qualitative content analysis of how team learning is described and framed in curricula. Additionally, the topic could be explored through interviews or case studies to gain deeper insight into actual practices. Instead of a national-scale analysis, such studies could focus on a single institution or program in greater depth.

These more in-depth approaches would complement and enrich the findings of the present data-driven analysis, offering a more nuanced understanding of how team learning is both described and enacted in engineering education.

4.2 Limitations

One limitation of this study is the abstract nature of curriculum-level data. It is likely that many valuable practices related to team learning are implemented at the course level but are not explicitly described in the curriculum documents. Therefore, the findings presented here reflect only what is officially documented. In addition, this study focuses solely on course descriptions and does not include broader program-level or degree-level objectives, which may also contain relevant information about teamwork and learning goals.

Another limitation is that some prerequisites refer to previous courses without detailing their content. As a result, team learning may be implicitly required through prerequisite courses, even if not explicitly stated in the course descriptions themselves. Furthermore, the dataset does not indicate whether courses are mandatory or elective, which prevents analysis of how course status may influence the emphasis on team learning. This distinction could have important implications for interpreting the findings and should be explored in future research.

4.3 Recommendations

We recommend that team learning be considered as a continuous, curriculum-level competence that develops throughout the degree program, rather than as an isolated activity within individual courses. Furthermore, we emphasize the importance of explicitly teaching and practicing team skills, instead of assuming that students already possess them. Clearer articulation of learning outcomes, teaching methods, and assessment criteria related to team learning would support more coherent and effective integration into engineering education.

5 THE USE OF AI

Artificial intelligence tools were used to support the preparation and reporting of this study. ChatGPT-4.5 was used to improve the clarity and readability of the manuscript, particularly in language editing.

AI was also used in the development of software tools for data collection (web crawler, ChatGPT-4) and initial screening (manual tagging interface, ChatGPT-4.5). The final code used in these tools was reviewed and verified by the first author.

The actual analysis and course classification were conducted without the use of AI.

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