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Research article

A theory-driven analysis of didactic foci in STEM-related teacher education master's theses

Jarkko Lampiselkä[1], Lauri Malmi[2], Arja Kaasinen[1], Päivi Kinnunen[1], Seyda Gul[3], Ozlem Oktay[3], İlknur Reisoğlu[4], Dilek Teke[3], Mustafa Sözbilir[3], Gülşah Atila[3], Ayşegül Yazar[3], Rumeysa Yildiz[3] and İlayda Güneş[3]

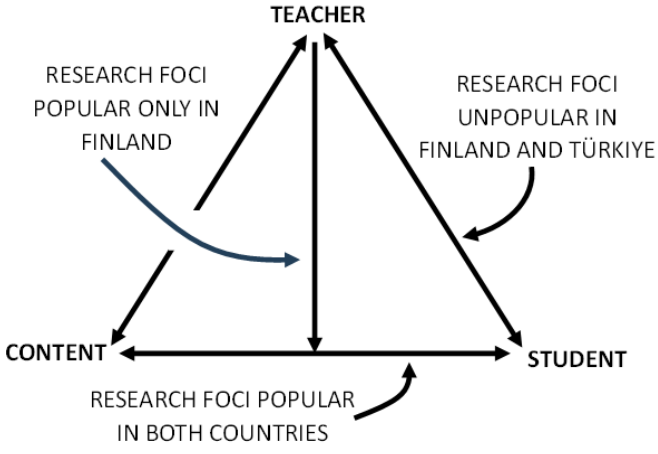
[1] University of Helsinki, Finland
[2] Aalto University, Finland
[3] Atatürk University, Türkiye
[4] Recep Tayyip Erdoğan University, Türkiye

Abstract: Master's theses often have limited visibility in research, even though they can unveil intriguing similarities and disparities between nations. Master's theses in subject-specific education provide a lens to teacher training traditions in different countries, which complements the view gained by analysing published research articles in journals and conference proceedings. The latter one emphasises interests of experienced researchers, while master's theses cover the perspective of a much wider population, teacher training students who aim at working as practising teachers, as well as their supervisors. In this study, we analysed 765 STEM education related master's theses in Finland and Türkiye, covering biology, chemistry, physics, and computing education and instructional technology. We employed an extended Herbartian didactic triangle as our theoretical framework and analysed the data using the didactic foci categorisation (DFC) method to study master's theses. The findings show that didactic relationships are studied much more often than pedagogical relationships. The most frequently investigated aspect in both countries was the student-content relationship, while teachers' pedagogical actions received frequent scrutiny only in Finland. Notably, there was limited exploration in both countries of teachers' reflections on students' perceptions and attitudes to goals/content and teachers' conceptions of students' actions in pursuit of these goals. These results underscore the need for a broader discussion regarding the scope and coverage of studying for a master's thesis within STEM-related teacher education.

Keywords:
pedagogical foci,
STEM education,
master's thesis,
teacher education,
didactic triangle

Correspondence:
jarkko.lampiselka@helsinki.fi

DIDACTIC TRIANGLE



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1 Introduction

This study investigates STEM-related master's theses in Finland and Türkiye, focusing on how they address pedagogical and didactic relationships as conceptualised in Herbart's didactic triangle. The purpose is to make explicit which aspects of teaching and learning are emphasised, which remain underexplored, and how these patterns reflect differences in teacher education traditions in the two countries.

Teacher education models across Europe vary significantly in their objectives, content, and structure (Zeichner, 2014). While some countries have adopted a practice-oriented approach, others emphasise research-based education which integrates scientific methods and fosters innovative thinking (Fiskum et al., 2025; Smith, 2015; Valle et al., 2025). In this context, master's theses are a focal part of research-based teacher education, reinforcing student teachers' research skills and preparing them for professional and academic growth. Since many graduates become schoolteachers, engaging students in systematic inquiry improves their competence, enhances classroom practice, and contributes to their school improvement efforts. Thus, a master's thesis is both an important part of evidence-based teaching, and is a tool for developing teachers' knowledge (Eklund, 2019; Eklund et al., 2019) as well as skills for their future profession (Fiskum et al., 2025).

Teacher education equips future teachers with essential knowledge, skills, and practical competencies for navigating complex classroom environments. These programmes integrate theory and practice, offering a unified vision of effective teaching and fostering university-school collaboration (Darling-Hammond et al., 2005). However, applying theoretical knowledge in real-world teaching often requires external support. Student teacher's conceptions of theory and its role in practice has tensions (Korthagen, 2010; Nägel et al., 2023; Van Schaik et al., 2018), such as how they conceptualise pedagogical theory vs. scientific theories (Sjølie, 2014). Studies have found that only 10% of teachers implemented new skills independently, while 90% required assistance (Bush, 1984; Fielding et al., 2005; Truesdale, 2003). This highlights the gap between teacher education and classroom realities, emphasising the need for better alignment between policy, teacher education, and classroom practice (Fullan, 2007). In this context, master's theses could serve as a bridge between theoretical knowledge and educational practice (Meeus et al., 2004).

A master's thesis is part of broader research collaboration, and its structure and content often reflect the research practices of universities and academic disciplines. In Finland, teacher training has been research-focused since the 1970s, including a requirement to write a master's thesis (Kansanen, 2014; Niemi et al., 2018), while in Norway, research-based teacher training was not introduced until 2017. Aspfors et al. (2021), Fiskum et al. (2025), and Valle et al. (2025) investigated teacher educators' views on teacher training in these countries in 2019, shortly after the transition in Norway. Unsurprisingly, Finnish teacher educators had more experience in supervising master's theses, which was reflected in their more positive views on various aspects of research-

based teacher training (Aspfors et al., 2021). In more detailed interview studies, two perspectives of the role of the master's thesis were identified: a narrow one focused on developing the skills needed to write the thesis, and a broader one, in which the process was seen as supporting students in becoming life-long learners (Fiskum et al., 2025). In both countries, teacher educators' views on research-based teaching, student engagement in research activities, the use of research literature, and the promotion of critical thinking, were similar. However, differing academic backgrounds and the competing demands of research and teaching appeared to create some tension among Norwegian teacher educators (Valle et al., 2025). A few years later, a follow-up interview study with Norwegian teacher educators revealed generally positive views on the role of the master's thesis in teacher training, although some concerns remained regarding its impact on future classroom teaching and educators' own supervision skills (Jegstad et al., 2022).

Sin (2012) states that in England, a master's thesis mainly aims to develop research skills, while in Denmark and Portugal, it represents independent research. Master's students in Denmark or Portugal may join research groups and contribute to broader research projects, and some students may publish their thesis findings in academic journals. The main goal of a master's thesis is to generate scientific knowledge, even though it can serve an instrumental purpose and student teachers may prefer development-oriented projects to traditional research papers.

Thus, the above findings suggest that analysing master's theses could provide insight into research trends, methodologies, gaps, which would aid the evolution of future studies. Previous studies have highlighted the significance of such analyses (Drysdale et al., 2013) and informing educational programme reforms by identifying shifts in academic focus (Conrad et al., 1993).

Several studies have compared teacher education in Finland and other countries—for example, Finland and Norway (Aspfors et al., 2021; Fiskum et al., 2025; Valle et al., 2025), Finland, France, and Morocco (Barzane et al., 2020), Canada, Denmark, Finland, and Singapore (Rasmussen & Bayer, 2014), Finland and Türkiye (Baskan et al., 2013; Ekoç, 2022), and Finland and England (Webb et al., 2004). However, these studies have primarily focused on programme structure and organisation, curriculum content, and teacher educators. Our work focuses on master's theses as the outcome of teacher training programmes in Finland and Türkiye — two countries with quite different teacher education systems. While previous research has examined master's theses in these countries with a focus on research methodologies (Oktay et al., 2025), we have concentrated on the didactic perspectives presented in the theses. There has been little research which focuses on these perspectives in comparative research. These are summarised in the next section.

The Finnish teacher education model has influenced reforms in other countries, including Norway. Since the 1970s, Finland has emphasised research-based teacher education, fostering teacher expertise, autonomy, and trust (Kansanen, 2014; Niemi et al., 2018). Finnish teachers develop curricula, design instructional plans, and assess students with minimal external oversight. Unlike many systems, Finland has not conducted school

inspections for over three decades, nor does it regulate textbooks or monitor classroom teaching (Niemi et al., 2018). This higher than normal level of professional freedom places significant demands on teacher education programmes. Unlike those in Finland, Turkish teachers have limited professional autonomy, particularly in decision-making (Canbolat, 2020). They must implement state-mandated curricula and often learn about their responsibilities only after policies have been set (Ünver, 2021). In-service training emphasises theory over practice (Kesen & Öztürk, 2019). While school leaders promote trust, they also monitor classroom teaching, and school inspections may soon resume after a decade-long hiatus. These structural differences shape distinct teacher education systems in Finland and Türkiye.

Teacher education programmes in Finland and Türkiye shape both school practices and teachers' professional growth. In Finland, master's theses are deeply integrated into teacher training, promoting pedagogical research and real-world application (Eklund, 2019; Eklund et al., 2019). In Türkiye, however, teacher education lacks this research-intensive component, with theses often focusing on theory over practice (Oktay et al., 2025). This contrast highlights key differences in research-practice integration and offers insights into how nations bridge the gap between academic research and teaching.

This study analyses master's theses using the Herbartian didactic triangle (Peterssen, 1989). This framework conceptualises teaching-learning dynamics through three key elements: the teacher, the student, and the content (Kansanen & Meri, 1999). The pedagogical relationship describes how teachers guide students, balancing expertise and student-centred facilitation (Kansanen, 2003). The didactic relationship refers to how teachers interpret and transform content to enhance learning. While the triangle functions as a whole, research often examines teacher-student (pedagogical) interactions and student-content (didactic) engagement separately (Kansanen & Meri, 1999).

2 Comparative studies of master's theses in education

Comparative studies enhance the understanding of a topic by offering alternative cultural, economic, political, and ideological perspectives (Schreiner & Sjøberg, 2004). They are valuable for policymakers, helping identify factors that shape educational outcomes (Meyer & Benavot, 2013). Organisations like UNESCO, the World Bank, and the OECD often conduct such studies. While most comparative research explores broad trends in international journals, master's theses provide detailed insights into student-supervisor goal setting, methodological competencies, and programme outcomes (Arisó et al., 2019; de Kleijn et al., 2013; Ringstad, 2013).

Comparative educational research examines teacher education policies and programmes, content, goals and recruitment programmes (Barzane et al., 2020; Beach & Bagley, 2013; Boichenko et al., 2019; Fiskum et al., 2025; Rasmussen & Bayer, 2014; Roodi, 2024), curricula (Sin, 2017), teacher professionalism (Drew et al., 2007), thesis supervision practices (Fujimoto-Adamson et al., 2024), and various sociocultural factors

like stress, autonomy, and gender disparities (Eres & Atanasoska, 2011; Helgøy & Homme, 2007; Jacob et al., 2020). Studies on master's theses explore themes such as thesis topics and approaches, creativity, educational significance, supervisor feedback, and career impact (Drageset et al., 2025; Filippou et al., 2017; Hooley, 2017; Rosen, 2017; Ylijoki, 2001). Within STEM-related education, research covers general trends (Li et al., 2020) and discipline-specific studies, including chemistry (Eriksson & Nordrum, 2018), geography (Brooks, 2018), and disaster education (Sözcü, 2020). Additionally, comparative research has examined Finnish and Turkish education (Karamustafaoğlu et al., 2017; Oktay et al., 2025), as well as studies specific to each country (Eklund, 2019; Sözbilir et al., 2012).

Teo et al. (2014) examined two top-tier chemistry education research (CER) journals—*Chemistry Education Research and Practice* and the *Journal of Chemical Education*—as well as four leading science education research (SER) journals: *International Journal of Science Education*, *Journal of Research in Science Teaching*, *Research in Science Teaching*, and *Science Education*. Both CER and SER journals commonly focused on students' conceptual understanding, teaching methods, and learner characteristics. The most frequent topics in SER journals were conceptions of students and teachers (26%), teaching (20%), and classroom context (19%), while teacher education (5%) and sociocultural issues (2%) were the least addressed. In comparison, CER journals were more discipline-specific and paid less attention to informal learning and philosophical aspects of science. Sözbilir et al. (2012) found similar patterns in Turkish studies, identifying teaching (23%), learning (21%), and student perceptions (16%) as key focus areas, whereas curriculum (4%) and teacher education (2%) received minimal attention. Gül and Sozbilir (2016) reported comparable trends in biology education.

Eklund (2019) found that Finnish primary school teacher programme master's theses focused on didactics and teaching (39%), school-related tasks (25%), and health and wellbeing (10%), while teacher competence (7%) and curriculum (6%) were less explored. Li et al. (2020) analysed STEM education journals, showing that goals, policy, curriculum, evaluation, and assessment (47%) dominated, followed by K-12 teaching and teacher education (13%) and K-12 learning environments (12%). Less studied areas included history, epistemology, and STEM philosophy (6%), aligning with Teo et al. (2014), with these topics making up less than 1%. Li et al. (2020) also noted that postsecondary STEM education (2%) was the least explored area.

However, applied data-driven methods were used in the above-mentioned studies, resulting in different classification systems, thus making comparisons between studies difficult. For example, some studies separate teacher- and student-focused research, while others combine them. Similarly, some merge didactic and pedagogical relationships, while others distinguish between them. While data-driven methods are effective at showing published content, they fail to highlight what is missing. In contrast, our theory-based didactic foci categorisation (DFC) system not only identifies the types of research published but may also uncover potential areas yet to be explored.

3 Master's theses in Finnish and Turkish STEM teacher education

Both Finnish and Turkish universities regard a master's degree as a validation of a student's entry into the academic profession. However, disparities in STEM education and teacher education policies can lead to differing perspectives in the topics chosen for the master's thesis. Particularly in Finland, completing teacher education with a master's degree is likely to influence the selection of research topics, the coverage of pedagogical aspects, and research designs in master's theses.

Finnish teacher education follows a five-year, two-cycle system: a bachelor's degree (180 ECTS) and a master's degree (120 ECTS). Secondary school teacher training programmes include a major (e.g., chemistry), a minor (e.g., physics), and compulsory pedagogical study (60 ECTS). For example, at the University of Helsinki, 40% of majors in chemistry involve chemistry education, complemented by additional pedagogically oriented minor subjects. Pedagogical study covers general pedagogy, subject-specific pedagogy, and teaching practice. All science master's student teachers complete a 30–40 ECTS pedagogically oriented thesis when studying their subjects in the respective departments. However, computing education (CEIT/CS) differs from other STEM fields. CEIT/CS is not an independent school subject but is integrated into STEM curricula, with optional secondary school courses, thus teacher education programmes in higher education institutions varies. Some universities offer similar CEIT/CS teacher education programmes as in STEM fields, while others do not. Consequently, master's theses in CEIT/CS teacher education programmes explore a broader range of topics than are studied in traditional STEM theses, spanning school and university education (Malmi et al., 2023).

Teacher education in Turkish universities lasts four years, overseen by the Council of Higher Education (CoHE) and conducted within faculties of education. In 2018, the CoHE revised the curriculum, dividing courses into field education (45–50%), professional teaching knowledge (30–35%), and general culture (15–20%) (TEDMEM, 2019). After earning a bachelor's degree (240 ECTS), students can pursue a master's (120 ECTS, 2–3 years), requiring a minimum score of 55/100 in Academic Personnel and Postgraduate Education Entrance Exam (ALES), a Grade Point Average (GPA) of 2.00/4.00, and a university-specific exam or interview. The master's thesis accounts for 20–30 ECTS. Unlike Finland's teacher education, in Türkiye it is primarily undergraduate, with a master's degree being optional for career advancement, academic roles, or management positions.

In both Finland and Türkiye, a master's thesis is typically completed in the final year, spanning about six months. It involves independent research or development work, applying acquired knowledge to a complex problem. The resulting scholarly report demonstrates subject and methodological mastery and contributes to the field (Kushkowski et al., 2003). Unlike in doctoral research, there is no requirement to generate

entirely new scholarly knowledge (Demb & Funk, 1999); rather, incorporating practical or scholarly innovation is recommended such as new learning resources or tools with a small-scale evaluation study (Şen, 2013).

Master's theses in both Finland and Türkiye can be methodologically highly diverse, applying experimental, non-experimental, interactive, analytical, or involve mixed methods approaches (Oktay et al., 2025). They can be theoretical or empirical. In Finland, students generally work independently under the supervision of an experienced scholar. The supervision may take place in various forms, e.g., personal meetings, group meetings, or thesis seminars. Thesis evaluation is carried out by the supervisor, and in most cases, with a second, independent evaluator (Filippou, 2019; Filippou et al., 2017). In Türkiye, students are supervised by an assistant, associate, or full professor, with evaluation by three faculty members, including one from another university. If a thesis is deemed to be insufficient, students receive a three-month extension for revisions, after which the same jury reassesses it for acceptance or rejection (Yükseköğretim Kurulu, 2016).

Finnish teacher education places a strong emphasis on research-based teacher preparation, equipping students with the necessary knowledge, skills, and abilities to study effectively. When this robust expertise is combined with the Finnish education culture, in which developmental studies are frequent (Oktay et al., 2025) and teachers are motivated to reflect on their own teaching practices (Körkkö, 2021), it makes classroom investigations popular. In contrast, classroom investigations in Türkiye are rare. Most Turkish teachers hold only a bachelor’s degree, and those pursuing a master’s often do so for career advancement. As a result, Turkish theses tend to focus on large-scale data analysis rather than small-scale educational contexts (Oktay et al., 2025).

Finnish teacher education promotes high professional autonomy and responsibility (Niemi et al., 2018). Teachers are well-trained to assess their practices, improve classroom instruction, and adapt to students' needs, leading to more master's theses on didactic activities and student reflections (Oktay et al., 2025). In Türkiye, master's students face practical and pedagogical limitations. Restricted classroom access makes classroom studying less common, and limited teacher autonomy (Canbolat, 2020) reduces interest in researching teachers’ didactic activities (Oktay et al., 2025).

4 Research questions

This study examines education related master's theses in biology, CEIT/CS, chemistry, and physics, fields commonly linked to STEM education. Our research stems from our background as STEM teacher educators in Finnish and Turkish universities. We emphasised STEM due to its crucial role in educational policies worldwide, fostering metacognitive skills and scientific literacy (Marginson et al., 2013). Additionally, organisations like the European Commission, European Schoolnet, and the EU STEM Coalition highlight the importance of STEM skills in driving economic growth, innovation,

and competitiveness (Bacovic et al., 2022). Our aim with this study was to identify which aspects in Herbartian didactic triangle (teachers, students, learning goals, or content) are addressed and which complex relationships between them are being studied. This analysis has the potential to contribute solutions to respond to issues that are common problems across all countries, such as improving educational outcomes. Furthermore, the examination of master's theses offers valuable insights into the state of research within a specific domain and can serve as a powerful tool for understanding trends in theory development, methods, themes, and gaps within that domain. Additionally, this study can assist in revising, reconstructing, and transforming educational programmes. The specific research questions are as follows:

1. To what extent do Finnish and Turkish STEM-related teacher education master's theses address pedagogical and didactic relationships as conceptualised in Herbart's didactic triangle?
2. What specific aspects of pedagogical and didactic relationships in Herbart's didactic triangle receive emphasis or remain under-explored in Finnish and Turkish STEM-related teacher education master's theses?

5 Method

5.1 Data collection

The dataset includes 164 Finnish and 601 Turkish master's theses in biology, chemistry, CEIT/CS, and physics education, published between 2015 and 2019, all within a teacher education context. Only electronic theses were included in the dataset, as there were few print versions. Finnish theses were accessed via university library databases (see the Data availability statement for the list of databases), while Turkish theses were obtained from the Higher Education Council of Türkiye National Thesis Centre. The dataset consisted of all available master's theses, without any selection bias, such as choosing only the highest- or lowest-quality works. The difference in the number of master's theses from each country is due to the population difference between the countries, and consequently the difference in the number of master's level students (FI population: 5.5 million; TR population: 84 million). The dataset was intentionally restricted to 2019, as the COVID-19 pandemic caused a substantial disruption in school education, making the data from 2020 to 2023 unrepresentative. From 2023 onwards, the dataset remains incomplete, because in Finland, for instance, students typically require 9 to 24 months to complete their master's thesis. Overall, CEIT/CS theses were the most common, comprising 34% in Finland and 65% in Türkiye, while biology was the least common in Finland (15%) and chemistry in Türkiye (8%).

5.2 Analysis method

We used a specific document analysis method that allowed us to categorise the thesis according to their didactic focus to answer our research questions. The DFC (the didactic foci categorisation) method is grounded in Herbart's didactic triangle (Peterssen, 1989), later expanded by (Kansanen & Meri, 1999), with the addition of teacher's didactic actions, and further developed by (Kinnunen, 2009) by incorporating teachers' reflection and students' feedback, while also extending the triangle's scope from the school level to institutional, societal, and international levels.

The DFC method is a theory driven qualitative method for analysing educational research publications and theses. The DFC method includes eight primary categories based on the key components of the original Herbartian triad and their interrelationships (Figure 1). The pedagogical relationship involves student-teacher interactions, perceptions, and roles in learning, covering categories 2, 3, and 4. The didactic relationship focuses on instruction, including content, teaching methods, and learning outcomes, encompassing categories 1, 5, 6, 7, and 8. Some categories also include subcategories for greater detail and clarity, as outlined in Table 1. After the initial qualitative categorisation of the documents (in this case master's thesis), descriptive statistics based on the frequencies in each category is produced to get the overall picture of the results.

Figure 1. a) Herbart's original didactic triangle, b) Modified didactic triangle with coding rubrics (Kinnunen, 2009).

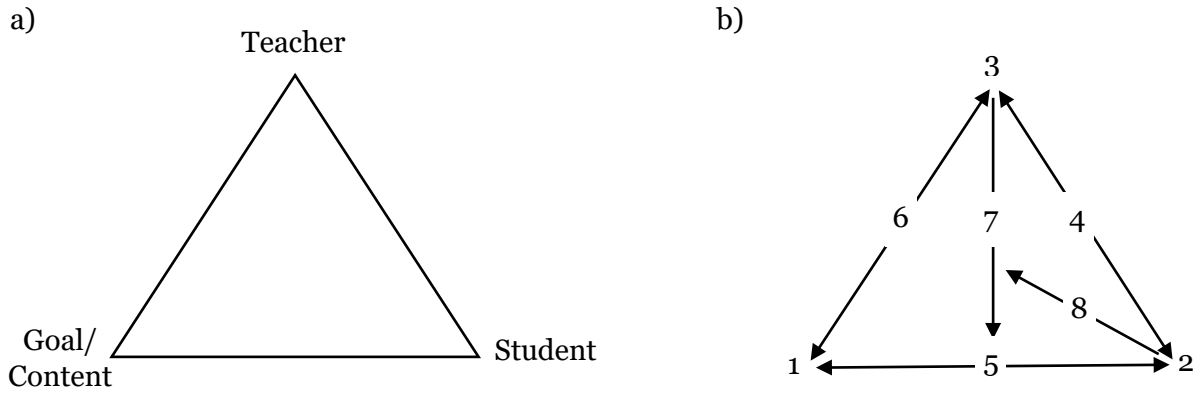
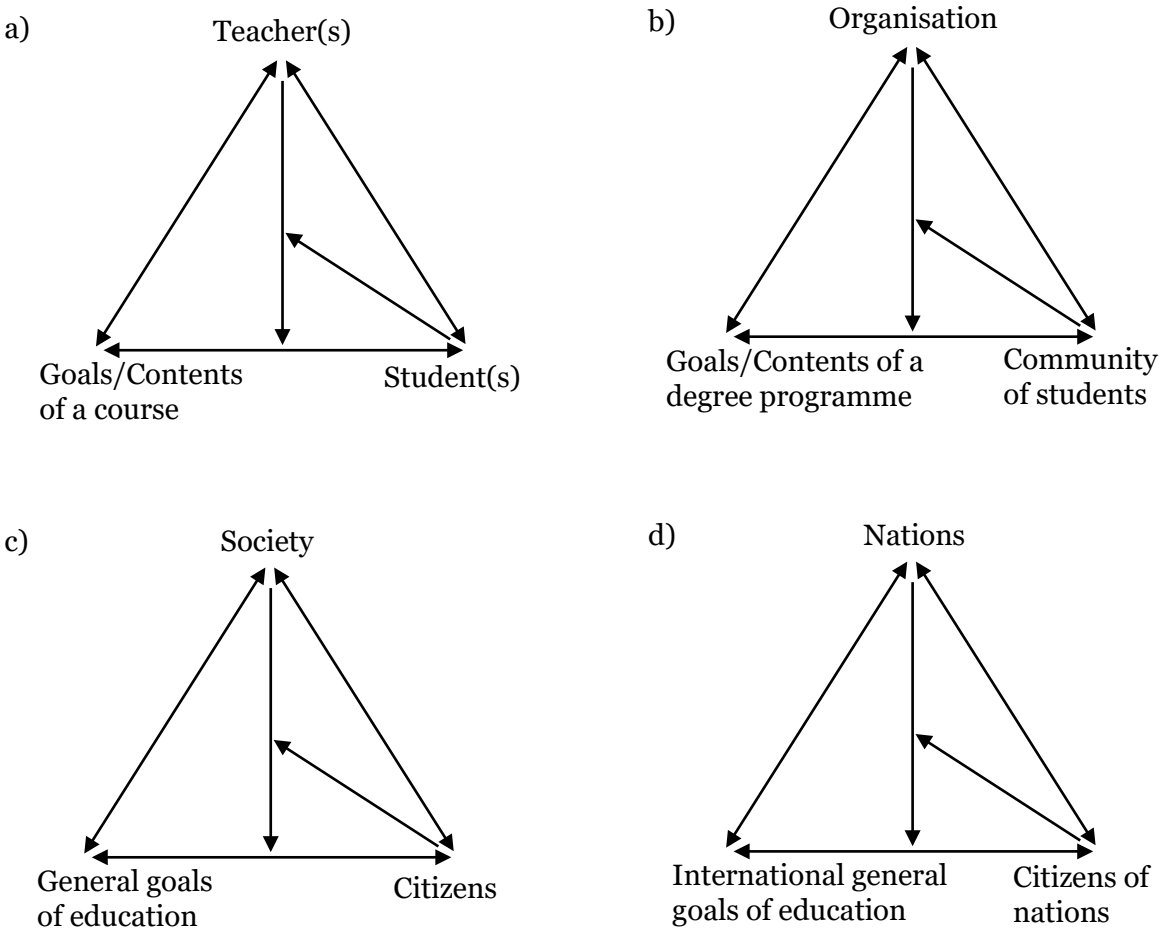


Table 1. The list of didactic foci and their definitions.

Category	Name of the didactic focus	Definition
1	Goals and content	The characteristics of the goals and/or contents of a course, or a study module of a degree programme. The relationship between the goals and the content in one level (course, degree, general goals of education) or between levels. An example thesis containing this focus: (Alasalmi, 2020).
2	Students	The students' characteristics (e.g. gender, level of education, knowledge, or prior learned skills of students). The students' relationships with fellow students or the community of students. An example thesis: (Ursin, 2015).
3	Teachers	The teachers' characteristics. The interactions between teachers. An example thesis: (Soysal, 2018).
4	Relationship between student and teacher	How students perceive the teacher (e.g. studies on how competent students think the teacher is) or the teacher perceives the students. An example thesis: (Takalo, 2017).
5	Relationship between student and goals	The students' actions when they are striving to achieve the goals. How students perceive course goals/contents.
5.1	Students' understanding of and attitude about goals and contents	How students understand a central concept of the course or how interesting students/ future students find the topic/degree programme/certain occupation. An example thesis: (Ekinci, 2015).
5.2	The actions (e.g. studying) the students do to achieve the goals	Students' actions include all actions/lack of actions that are in relationship to learning and achieving the goals. An example thesis: (Vuola, 2018).
5.3	The results of the students' actions	The outcome of the study process, e.g. a study that includes a discussion of the learning outcomes after using a new teaching method. An example thesis: (Joensuu, 2020).
6	Relationship between teachers and goals/ contents	How teachers understand, perceive, or value different aspects of the goals and contents. An example thesis: (Erkkilä, 2019).
7	Teachers' didactic actions	A teacher's relationship with a student's relationship to the goals and content of a course.
7.1	Teachers' conceptions of students' understanding of/attitude to goals/ contents.	What teachers think about how students understand goals and content, or what students' attitudes are about goals and content. An example thesis: (Boz, 2019).
7.2	Teachers' conceptions of students' actions towards achieving goals	Teachers' perceptions of students' actions (e.g. studying). An example thesis: (Blomberg, 2018).
7.3	Teachers' didactic activities	Teachers' didactic actions (e.g. lecturing, providing a learning environment, and assessment methods). An example thesis: (Lukkarinen, 2016).
7.4	Teachers' reflections on their own didactic actions	To what degree teachers think the new teaching method was successful. An example thesis: (Soysal, 2018).
8	Relationship between students and teachers' didactic actions	How the students feel about the teachers' didactic actions (e.g. course feedback). An example thesis: (Soysal, 2018).

The extended didactic triangle framework (Kinnunen, 2009) allows for analysis across several levels of data collection (Figure 2), helping to contextualise each thesis. Data may come from individual teachers in a single course, aligning closely with Herbart's didactic triangle. Alternatively, data can span multiple courses within a study programme, an entire programme, covering nationwide trends at societal level, or at an international level, incorporating multiple countries for a broader perspective.

Figure 2. Extended didactic triangle based on educational scope. a) teacher/course level, b) teaching organisational level, c) society level, and d) international level.



For a single thesis, the number of foci may vary widely. Some theses have multiple foci, with only some studied, while others may have very few foci that are examined extensively. By consensus, the research team decided to include a maximum of three foci reported in the results section of each thesis. Our decision to limit the number of foci to three was affected by our previous experience developing and using this same method. On one hand, including fewer foci enhances the risk of excluding relevant aspects of the study. On the other hand, including more than three foci tends to lead into difficulties drawing a line between what is regarded as a big enough emphasis to warrant including it as focus. Furthermore, in our previous studies in which we had not delimited the number of foci, the average has been just below or above two foci per study (Kinnunen et al., 2014;

Kinnunen et al., 2016), which suggests that including a maximum of three foci will capture the most essential foci in our data. This approach ensured the analysis captured the most significant and relevant themes, providing a comprehensive understanding of the key didactic issues addressed. Each focus was selected for its alignment with the framework of the didactic triangle, maintaining a coherent and structured analysis. This framework ensured that the foci selected were pedagogically sound and relevant. Studies that did not align with the didactic triangle, such as literature reviews or evaluations of the technical aspects of organising massive open online courses (MOOCs) without pedagogical perspectives, were excluded.

5.3 Analysis process

Finnish and Turkish researchers analysed theses separately due to language differences, as many were written exclusively in Finnish or Turkish. Data were initially collected using the Online Educational Research Papers Classification Form (Sözbilir et al., 2012) and transferred to Microsoft Excel. The Turkish research team compiled and merged the Finnish and Turkish datasets.

For comparative analysis, five English-language theses from each country were randomly selected. For the cross-analysis, we required master's theses written in English, but such theses were scarce. To ensure adequate representation across countries and subjects and to avoid overweighting any one field, we limited the cross-analysis sample to five theses. In both data pools, more than 90% of the English-language theses were in CS/CEIT, with only six master's theses outside this field in total. Each team member independently categorised them, and inconsistencies were resolved through joint discussions. The interrater reliability coefficient, calculated using the formula used by(Miles et al., 2014), indicated strong agreement (0.85).

The researchers took the whole thesis into consideration when identifying the focus or foci of the study. This labour-intensive approach was necessary because based on our experience using this method, not all relevant foci are always explicitly stated in a specific section of the thesis, such as, an abstract or an introduction section of the thesis. Therefore, we proceeded by looking at the thesis when we analysed each thesis. Oftentimes the most prominent foci were found when reading carefully the following sections: abstract, introduction, research questions, and results. For more detailed examples of the analysis process, please see (Kinnunen et al., 2016; Lampiselkä et al., 2019). Taken the substantial number of theses in our database we also needed several researchers to do the actual analysis.

In Finland, researchers worked in pairs within a single discipline, discussing discrepancies at joint meetings. In Türkiye, a researcher from each STEM field analysed the corresponding theses. After completing individual analyses, both teams collaboratively reviewed the results to enhance coding validity and reliability. In cases in which it was unclear which focus, or foci, should be chosen, the thesis was discussed with a larger group of researchers until full agreement was reached.

5.4 Strengths and limitations of the methodological choices

Our methodological choices provided a systematic approach to analysing theses with a solid theoretical foundation. This allowed us to position our results within broader science education research and compare them with existing and future studies using similar frameworks. However, a limitation of theory-based analysis is its inability to capture aspects outside the framework chosen. Since the didactic triangle is based on formal education, theses addressing informal learning fall outside its scope. To ensure analytical quality, we clearly defined each category and trained the research team in the analysis schemes. We also calculated interrater reliability, and in cases of uncertainty, discussed theses collectively to reach well-founded categorisations.

6 Results

This section presents the findings in relation to the research questions.

RQ 1: To what extent do Finnish and Turkish STEM-related teacher education master's theses address pedagogical and didactic relationships as conceptualised in Herbart's didactic triangle?

Finnish and Turkish master's theses predominantly examined didactic relationships (Categories 1, 5–8), with pedagogical relationships (Categories 2–4) receiving less attention. In total, 96% of Finnish and 81% of Turkish theses focused on didactic relationships, while only 4% and 19%, respectively, addressed pedagogical relationships. Qualitative differences were observed between the countries in the research focus. In Finland, studies on the didactic relationship emphasised the teacher's didactic actions more than in Türkiye, where the focus was primarily on the student. While differences in the pedagogical relationship were less pronounced, Turkish research still highlighted the student's role. Table 2 provides a breakdown of these foci. In the Finnish data, a total of 321 foci were identified in 164 theses (an average of 1.96 foci per thesis). At least partly, the difference in the average figures can be explained by the fact that qualitative and mixed-method studies were more common in Finland than in Türkiye (Oktay et al., 2025). Such studies typically employ complex research designs and require a diverse set of research questions, which in turn leads to a higher number of foci per thesis.

Table 2. Distribution of the frequency of didactic emphases according to the DFC -method (see Table 1) in theses belonging to various categories in Finland and Türkiye.

	FINLAND		TÜRKİYE	
Didactic focus of thesis	**f**	**%**	**f**	**%**
Pedagogical relationship				
2. Student	8	2.5	120	12.7
3. Teacher	3	0.9	50	5.3
4. Relationship between student and teacher	1	0.3	5	0.5
Didactic relationship				
1. Goals and Contents	31	9.7	40	4.2
5. Relationship between student and goals	111	34.6	577	61.1
5.1 Student's understanding of and attitude about goals and contents	54	16.8	262	27.7
5.2 The actions (e.g. studying) taken by the student to achieve the goals	22	6.9	40	4.2
5.3 The results of the student's actions	35	10.9	275	29.1
6. Relationship between the goals/contents and the teacher	6	1.9	67	7.1
7. Teachers' didactic actions	112	34.9	59	6.2
7.1 Teacher's conceptions of student's understanding of/attitude to goals/contents	-	-	11	1.2
7.2 Teacher's conceptions of students' actions towards achieving goals	1	0.3	6	0.6
7.3 Teacher's didactic activities	81	25.2	13	1.4
7.4 Teacher's reflections on his/her own didactic actions	30	9.3	29	3.1
8. Relationship between student and teacher's didactic actions to enhance learning	48	15.0	3	0.3
Total	**321**	**100.0**	**945**	**100.0**

RQ2: What specific aspects of pedagogical and didactic relationships in Herbart's didactic triangle receive emphasis or remain under-explored in Finnish and Turkish STEM-related teacher education master's theses?

Both countries demonstrated strong interest in students' understanding and attitudes within the didactic relationship, though these topics were notably more prevalent in Türkiye. In contrast, Finnish research emphasised teachers' didactic actions significantly more, including student feedback on teaching methods. While pedagogical relationships received limited attention, Turkish students showed greater interest in student characteristics. The teacher-student pedagogical relationship remained particularly under-explored.

In both Finland and Türkiye, the student-content relationship (Category 5) was the most extensively studied aspect of the didactic relationship. It accounted for 35% of Finnish and 61% of Turkish theses, though with different emphases. Turkish student teachers focused more on students' understanding and attitudes to goals and content (Category 5.1), comprising 28% of Turkish theses, compared to 17% in Finland. Similarly, Turkish theses placed more emphasis on the results of students' actions (Category 5.3) at 29%, whereas Finnish theses covered this aspect in only 11% of cases.

Another frequently examined aspect was teachers' didactic actions (Category 7). However, qualitative differences emerged between the countries. Finnish theses focused significantly more on this area (35%) compared to Turkish theses (6%). Finnish student teachers examined teacher-led instructional strategies (Category 7.3) far more frequently (25%) than Turkish students (1.4%). Additionally, teacher self-reflection (Category 7.4) was more commonly addressed in Finnish theses (9%) than in Turkish theses (3%), suggesting a stronger emphasis on professional development in Finland.

The relationship between student and teacher didactic actions to enhance learning (Category 8) also emerged as an important distinction. Finnish students explored this topic more frequently (15%) than Turkish students did (<1%).

Compared to the didactic relationship, pedagogical aspects (Categories 2–4) were studied far less often in both countries. Among these, student-related aspects (Category 2) were examined more often in Türkiye (12.7%) than in Finland (2.5%). This suggests a relatively stronger emphasis on understanding student characteristics and learning experiences in Turkish research.

Despite the strong focus on didactic relationships overall, some subcategories remained under-explored. Teachers' conceptions of students' understanding (Category 7.1) and teachers' perceptions of students' actions about learning goals (Category 7.2) were infrequently addressed. Less than 1% of Finnish theses and about 2% of Turkish theses focused on either of these aspects.

Although the student-goals relationship (Category 5) was widely studied, little attention was given to how students actively engage in lessons to achieve learning goals (Category 5.2). Only 6.9% of Finnish and 4.2% of Turkish theses investigated this aspect.

Among pedagogical aspects, teacher characteristics (Category 3) received minimal attention in both countries, totalling only 5.3% of Turkish and 0.9% of Finnish theses. The least studied focus area in both Finnish and Turkish theses was the student-teacher relationship (Category 4). Only one Finnish thesis (<0.3%) and five Turkish theses (0.5%) investigated this aspect, highlighting a significant gap in research.

Despite the overall lack of focus on pedagogical relationships, the student-teacher dynamic remained particularly under-explored in both countries, appearing in less than 1% of theses.

7 Discussion

As shown in the Results section, most Finnish and Turkish master's theses focused on didactic relationships, particularly student-content interactions, and teacher didactic activities (Categories 5 and 7). This section contextualises these findings by comparing them with earlier research and discussing their implications for teacher education.

Thirty-five per cent of Finnish master's theses and nearly 61% of Turkish theses focussed on student-content relationship, which is consistent with earlier studies. In comparison, 52% of CEIT/CS related dissertations and master's theses focused on learning outcomes (Drysdale et al., 2013), 40% of science education studies in Türkiye focused on students' understanding, attitudes, learning styles, and achievements (Sözbilir et al., 2012), and 42% of Nordic science education studies and 53% of European Science Education Research Association (ESERA) conference studies focused on the student-content relationship (Lampiselkä et al., 2019). Kansanen and Meri (1999) argue that understanding the student-content relationship is crucial for teachers' didactic comprehension and aligns with achieving curriculum goals, thereby emphasising its popularity among researchers. However, there was a significant difference in the popularity of this focus between Finland and Türkiye. This could be explained by differences in emphasis within national secondary level education. Elmas et al. (2020) demonstrated that the Turkish upper-secondary chemistry curriculum is more detailed, structured, and has a significantly higher number of objectives (127) compared to the Czech and Finnish curricula (15-17 objectives each). A more content- or goal-oriented school curriculum undoubtedly increases the focus on studying the student-content relationship in Turkish master's theses.

Studies on teachers' didactic actions (Category 7) were popular, but significant differences between Finland and Türkiye persisted. While almost 35% of the Finnish theses focused on this area, only 6% of the Turkish studies did the same. The Finnish data are in line with earlier studies, which showed that 35% of the master's thesis and doctoral dissertations focussed on instructional design (Drysdale et al., 2013), and 38-39% of Finnish primary school teacher education programme master's thesis focussed on the didactics and teaching (Eklund, 2019). The focus area seems to be slightly more popular within thesis works if compared with scholarly publications. About 27% of articles in the NorDiNa journal and 26% of papers at the ESERA conference (Lampiselkä et al., 2019), and 23% of Turkish science education studies (Sözbilir et al., 2012) focused on this topic. The disparity in frequency between Finnish master's theses and scientific articles could be attributed to the authors' backgrounds. There appears to be an increasing interest and motivation among student teachers to explore their own teaching methods, especially since their development as teachers is ongoing (see e.g. Niemi et al., 2018). This assertion finds support in Eklund (2019) study of Finnish master's theses, in which she found that 38-39% of the theses focused on didactics and teaching. Among these, a majority (53%) centred on the teacher's perspective, while the learner's perspective was examined less often (38%). However, it is challenging to find a plausible explanation for the notably low

interest in studies on teachers' didactic activities within the Turkish master's theses. This outcome likely arises from several factors, such as the content and goal orientation of the secondary school curriculum, students' preference for completing their thesis quickly or easily, and the inherent challenges of conducting teaching experiments in classroom settings.

Teachers' self-reflection is a well-established and integral practice in European education systems, supported by policies, professional standards, initial teacher education, continuous professional development programmes, and cultural values that emphasise lifelong learning and improvement (see e.g. Volles, 2016). However, the differences between Finnish and Turkish teacher education traditions are partly reflected in the quantitative disparities observed in classroom surveys between the two countries. This distinction is further underscored by the varying numbers of papers focused on teachers' reflection and student feedback. This study showed that Finnish student teachers (9%) seem to be more interested in self-reflection than Turkish students (3%), even though this topic is one of the least studied aspects of the didactic relationship. The lack of studies on teachers' self-reflection is in line with the Nordic science education research area (6%) and ESERA conference papers (2%) (Lampiselkä et al., 2019). Perhaps this is due to the research trend in STEM education, which often prioritises measurable outcomes such as student achievement, learning styles, and instructional effectiveness. Self-reflection is more subjective and harder to quantify, making it less attractive for data-driven research approaches that seem to dominate research in STEM education. However, students' relationship to teachers' didactic activities gained more interest (Category 8). Fifteen per cent of the Finnish master's theses focussed on this topic, thus being one of the more popular single focus areas. In contrast, less than 1% of Turkish master's theses focussed on this topic.

Combining results within categories 5, 7 and 8 suggest that Finnish master's theses are more teacher centred, and Turkish ones more student centred. Finnish research shows a stronger commitment to exploring and enhancing instructional design and teaching methods, whereas although Turkish research addresses teaching, it places relatively less emphasis on didactic actions specifically. This indicates differing educational research priorities between the two countries. The significant differences in frequency suggest not just a statistical variation, but also fundamentally different approaches to teacher education. The emphasis on teacher reflection and didactic actions in Finnish theses (35%) contrasts sharply with the student-centred focus in Turkish theses (61%), indicating distinct research priorities and pedagogical traditions. Finnish teacher education emphasises teacher's self-reflection, continuous development, and lifelong learning (Niemi et al., 2018), which is reflected in the increased number of master's theses focusing on teacher's didactic activities, their reflections on these activities, and student feedback on these activities. The Turkish secondary school curriculum's strong content and goal orientation (Elmas et al., 2020), combined with low teacher professional autonomy (Canbolat, 2020; Ünver, 2021) and theoretically oriented in-service training (Kesen &

Öztürk, 2019), contributes to the rarity of classroom investigations, which manifest as student-centred approaches in master's theses.

In contrast to the didactic relationship, the pedagogical relationship received notably less attention in research. The student-teacher relationship (Category 4) was particularly under-explored, appearing in less than 1% of theses in both countries (Table 2). Similarly, teacher characteristics (Category 3) received little attention (Finland: 0.9%, Türkiye: 5.3%). This aligns with earlier findings in STEM education research, in which the teacher-student interaction is often overlooked (Lampiselkä et al., 2019). Additionally, teachers' conceptions of students' understanding and attitudes about goals and content (Category 7.1), as well as students' actions in achieving those goals (Category 7.2), were also studied only marginally, accounting for just 0–1% of the studies in both countries. Unfortunately, the finding aligns well with the study by Lampiselkä et al. (2019), about ESERA conference proceedings (0-2%) and NorDiNa journal articles (1-3%), underscoring the under-explored nature of the pedagogical relationship between students and teachers in STEM education research. Even though Eklund (2019) notes that teachers' and students' perspectives were among the more frequently applied in the master's theses, the researcher's or student teacher's own perspective were among the least frequently investigated (3-5%). Eklund (2019) has argued that students do not really see the master's thesis as an opportunity to investigate topics and choose methods that will equip them for their profession and develop them as teachers. Our finding corroborates this presumption, but based on our previous studies (e.g. Lampiselkä et al., 2019), the problem is wider than just master's theses. There is a growing recognition of the need to understand and support teachers better, as they are crucial agents of change in the educational system. Expanding research to include more studies on teachers could offer deeper insights into effective teaching practices and professional development needs, ultimately benefiting student outcomes as well. In our view, the situation is more challenging in the Turkish educational context than in the Finnish context. In Finland, student teachers show considerable interest in teacher self-reflection and student feedback, while in Türkiye, these topics are also very rarely studied. Overall, it is worrying that there has been little research on teachers and teacher-student interaction. Niemi et al., 2025 explored Finnish teachers' self-efficacy and beliefs in teaching mathematics and its impact on students' mathematics motivation. Pikk et al. (2025) focused on the relationship between teachers' beliefs about the nature of mathematics, the learning of mathematics, and self-efficacy beliefs among Estonian primary and secondary school teachers. Haataja and Salonen (2025) carried out a case study addressing various aspects of teachers' visual attention to their colleagues when co-teaching mathematics in a classroom in Finland. On the other hand, Bui et al. (2025) studied Finnish pre-service teachers' GenAI readiness, behavioural intentions, perceptions, and attitudes about the integration of Gen AI technologies in the classroom as well as their use of these tools in their teaching.

8 Limitations

The limitations of this study relate first to the data collection. The centralised database for all theses completed in Turkish universities made the data collection in Türkiye convenient and less prone to not being able to locate all relevant thesis. On the contrary, in Finland, each university has its own database, and there are variations on how to search theses (by department/programme, by topic, by keywords, etc.). We collected all accessible theses in the databases, based on using the search functions that were available. However, teacher education programmes in computing are not widely offered by universities. We therefore included all educational computing theses that we found in computing departments/programmes based on their title and/or abstract, because computing education research is carried out in many Finnish universities. It is possible that such theses are also available in other departments/programmes, if the thesis is carried out as a minor topic while registered by the major topic in students' degree. Comprehensive browsing of all theses in all programmes was not possible due to the scope of the work. However, we expected that the number of theses we did not locate would be low.

Second, the DFC is a theory driven analysis method and thus the theory that the method is based on poses some inherent restrictions. The DFC is based on the didactic triangle and its extensions and is thus more able to capture foci that relate to formal education context. Third, the process of identifying the foci areas in the theses was interpretive work. However, the Finnish researchers had been using and developing DFC methods for several years when analysing the scholarly literature in multiple venues (Kinnunen, 2009; Kinnunen et al., 2016; Lampiselkä et al., 2019), thus having extensive experience in applying the method. They trained the Turkish research group to use the method. Interrater reliability was applied to check the consistency of categorisation, with joint discussions to resolve differences. The Finnish team also applied pairwise analysis and extensive joint discussions to resolve cases in which the focus areas were multiple, which was more common in Finnish theses.

9 Conclusion

Our bilateral research collaboration critically examined master's theses within two distinct higher education systems. The novel theory-based analysis method served as a valuable tool for identifying patterns in the didactic foci of master's theses, specifically highlighting gaps within the field. Many studies analysing trends in STEM teacher education master's theses rely on data-driven methods, which primarily provide information about what has been studied and what exists in the data. In contrast, the theory-based DFC method employed in this study not only offers insights into what has been studied but also identifies gaps in the existing research. The theoretical method of data analysis is used much less often compared to the data-driven approach, making the findings of this study

especially valuable to the scientific community, particularly in under-researched areas.

The study showed that the DFC method yield results like data-driven methods. For example, (Lampiselkä et al., 2019) noted that the didactic relationship is extensively studied, and pedagogical relationship is rarely published in ESERA, and Kinnunen et al. (2016) found the same in relation to NorDiNa. This study confirms the same gap in master's theses, indicating a deficiency in academic publications across the various levels and settings. These under-researched areas merit further attention.

Second, the results suggest revision, reconstruction, and transformation of educational initiatives. While both countries aim to equip future teachers with the necessary knowledge, skills, and abilities for successful teaching, it appears that improvements in the pedagogical orientation of these studies and teaching practices may be needed. Finnish master's theses show a diverse range of foci, particularly emphasising teachers' didactic activities and the relationship between students and a teacher's actions. This suggests a holistic approach to understanding the educational process, with a significant interest in how teachers plan, execute, and reflect on their teaching. In contrast, Turkish master's theses exhibit a stronger focus on students, including their understanding, attitudes, actions, and results, indicating a more student-centred approach in pedagogical research aimed at improving learning outcomes. The relatively lower focus on the student's feedback in Türkiye suggests an opportunity to explore this area further, potentially enhancing the understanding of how teacher-student interactions impact learning. The Finnish emphasis on teacher reflection (both on didactic activities and their relationship with students) suggests a culture of continuous improvement and self-assessment among educators. It could be beneficial for Türkiye to consider incorporating such a practice more deeply into their pedagogical research.

Master's theses in both Finland and Türkiye overwhelmingly focus on the didactic relationship, aligning with broader research trends (Lampiselkä et al., 2019). However, this emphasis may come at the expense of pedagogical relationships, particularly the student-teacher interaction (Category 4), which remains under-explored in both contexts. The research results indicate that in Finland and Türkiye, as in any other country, it would be worthwhile to examine the research roadmap for master's theses in teacher education. This has implications not only for the critical examination of theses written in teacher education, but also more broadly for other research, education policy, and, of course, teacher education practices. Future research should address this gap by focusing on how teacher-student interactions influence learning outcomes. This study clearly indicates that the teacher-student pedagogical relationship is underrepresented in research, representing a blind spot in the field of science education. Other studies in the field support this finding, demonstrating that regardless of the publication channel, teachers' conceptions of students' understanding of/attitudes about goals/contents and teachers' conceptions of students' actions toward achieving goals are inadequately investigated.

Research ethics

Author contribution

J.L.: conceptualisation, data curation, formal analysis, investigation, project administration, validation, visualisation, writing—original draft, writing—review and editing
L.M.: conceptualisation, data curation, formal analysis, investigation, validation, writing—review and editing
A.K.: conceptualisation, data curation, formal analysis, investigation, validation, visualisation, writing—review and editing
P.K.: conceptualisation, data curation, formal analysis, investigation, methodology, validation, visualisation, writing—review and editing
S.G.: data curation, formal analysis, investigation
O.O.: data curation, formal analysis, investigation
İ.R.: data curation, formal analysis, investigation
D.T.: data curation, formal analysis, investigation
M.S.: conceptualisation, data curation, formal analysis, investigation, project administration, validation
G.A.: data curation, formal analysis, investigation
A.Y.: data curation, formal analysis, investigation
R.Y.: data curation, formal analysis, investigation
İ.G.: data curation, formal analysis, investigation.

All authors have read and agreed to the published version of the manuscript.

Artificial intelligence

The main text of this manuscript has been language-edited using the ChatGPT 4o language version solely as a tool for checking and correcting syntax and grammar. The final version of the manuscript has been checked and revised by a native English speaker.

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Our research strictly followed the ethical guidelines set forth by the author's universities. Notably, this study did not involve medical treatments or minors, obviating the need for approval from the local research ethics committee. All data collected were used solely for the purposes of this study, and we diligently ensured the protection of human rights and dignity throughout our research.

Informed consent statement

The study did not involve human participants.

Data availability statement

Finnish master's theses were retrieved from these universities' electronic repositories:

- Aalto University – Aalto University Repository (https://aaltodoc.aalto.fi)
- Lappeenranta – Lahti University of Technology - LUTPub – LUT University Institutional Repository (https://lutpub.lut.fi)
- University of Eastern Finland – UEF Electronic Publications (https://erepo.uef.fi)
- University of Helsinki – Helka / University of Helsinki Digital Repository (Helda) (https://helda.helsinki.fi)
- University of Jyväskylä – Jykdok / JYX Digital Repository (https://jyx.jyu.fi)
- University of Oulu – Jultika – University of Oulu Repository (https://jultika.oulu.fi)
- University of Lapland – Lauda – University of Lapland Institutional Repository
- (https://lauda.ulapland.fi/)
- University of Tampere – Trepo – Tampere University Repository (https://trepo.tuni.fi)
- University of Turku – UTUPub – University of Turku Publication Archive (https://www.utupub.fi)
- University of Vaasa – OSUVA Open Science – University of Vaasa Publication Archive (https://osuva.uwasa.fi/handle/10024/174)

Turkish master's theses were retrieved from the national centralised thesis database maintained by the Council of Higher Education (YÖK Tez Merkezi): https://tez.yok.gov.tr/UlusalTezMerkezi.

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Conflicts of interest

The authors declare no conflicts of interest.

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