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Research on teaching and learning in Physics and Chemistry in NorDiNa Papers

Abstract

This article provides an overview of teaching and learning processes in research on physics and chemistry education published in NorDiNa 2005–2013. Using the didactic triangle as our theoretical framework we developed a typology to analyse the data and used this to categorise 89 related research papers, from all levels of education (primary, secondary and tertiary). The results suggest that students' characteristics, their understanding of the content and learning outcomes are studied frequently. In contrast, science teachers are studied much less. Most papers reported studies that had been done at the teaching organisation level. Course level studies and society level studies were also frequent. However, international level studies were few in this data pool. We conclude by discussing less popular research topics in the science education field.

1. INTRODUCTION

The concept *instructional process* covers all teaching and learning activities, which are carried out by teachers and learners reaching from goal setting and planning to evaluation of learning results. A holistic understanding of the instructional process is important for anyone who is striving for quality

of such processes. Such understanding could be obtained by conducting systematic research on the different aspects of the instructional process. The research community as a whole could achieve a versatile and holistic understanding about the instructional process, even though individual researchers need to concentrate on narrower themes. This may seem obvious. We wish to raise the question, however, whether we, as a research community, have studied the instructional process from a wide enough range of viewpoints. Which aspects of teaching and learning would benefit from more studies adding to a more holistic understanding?

Here we analyse physics and chemistry education research papers written by Nordic authors and published in NorDiNa in 2005–2013. The results reflect in part our interest in a Nordic research community; and the frequency of aspects of the instructional process reported on in NorDiNa. Our main research questions are:

1. *On which aspects of the teaching and learning process have physics and chemistry education publications in NorDiNa focussed?*
2. *With what frequency are teaching and learning process related aspects studied? What aspects are much studied and what aspects are under-researched in NorDiNa?*

We also study the following questions, which provide additional information that helps us to form an overall picture of what has been studied and whether there are any differences among countries.

3. *Which educational levels does physics and chemistry education research published in the NorDiNa focus on?*
4. *What differences are there in the focus of researchers who published in NorDiNa in the different Nordic countries?*

First, we discuss the existing categorisation systems that other researchers have used to get an overview of publications in science education and related fields. Together sections three, four, and five describe the methodology we used in this study. In section three we introduce our theory-based categorisation system, based on the multi-layered didactic structure (Kinnunen, 2009). In section four we introduce the analysis process, in section five we discuss quality issues. In section six we provide the results and in the conclusion we summarise suggestions for new research topics.

2. LITERATURE REVIEW

Considerable work is carried out in science education and closely related areas seeking to build a big picture of the research field. We have looked at such work in science education research, physics and chemistry education research, mathematics education, computing education and engineering education research. We have identified several different aspects of research, which have been the focus in meta-analyses or categorisations. They include the contents of the research, that is, *what* is investigated, the research process, that is, *how* the research is carried out, and various stakeholders in the research, that is, *who* is doing the research and who is benefitting from it. From our perspective, only the “what” aspect is relevant here.

The recent status of research in science education has been investigated by Tsai & Wen (2005) and Lee, Wu, & Tsai (2009) who analysed 1671 papers published 1998–2007 in the *International Journal of Science Education*, *Science Education*, and the *Journal of Research in Science Teaching*. The researchers looked at trends in research topics (“what” aspect) and the educational level (from pre-school to university graduate level). In addition, they analysed the origin of the authors (“who” aspect), as well as the nature of the contribution, that is, whether the papers included empirical work, theoretical work, a review or presented a position (“how” aspect). When analysing the content of research, they split the papers into the following categories that were mainly adapted from the National Association for the Research in Science Teaching conference strand categories: Teacher Education, Teaching, Learning-Conception, Learning-Contexts, Goals, Policy, and Curriculum, Culture, Social

and Gender, Philosophy, History, and Nature of Science, Educational Technology, and Informal Learning. The most frequent categories were those related to teaching and learning (conceptions or contexts), which covered well over half of the analysed papers. Some trends also emerged. The share of papers focusing on Teaching, and Learning-Contexts had increased, while the share of papers considering Learning-Conceptions, Culture, and Social and Gender had decreased.

Later on Tsai, Wu, Lin, & Liang (2011) complemented this work by analysing the same three journals and the *Research in Science Education* journal looking only at studies concerning Asian students (N = 228). They used the same analysis methods, and found similar results concerning the most common areas. However, in this data set there was a trend that the number of papers in both Learning-Conceptions and Learning-Contexts categories had increased. Another extension of using the same categorisation scheme was carried out by Lin, Shu et al. (2012) who studied 43 papers published in eight journals in 1995–2009, that reported research on scaffolding in science education. They found that more than 70% of the papers had a focus on learning contexts, and the number of such papers had significantly increased during the time period.

In all of the previous works the papers were analysed manually. Chang et al. (2009), however, used scientometric methods, which automatically extracted content analysis information from the papers. They analysed 3039 articles, published 1990–2007 in the above-mentioned four journals. Their cluster analysis resulted in nine main categories, which covered 1401 papers (the remaining were considered outliers). The topics in the categories included Scientific concept, Instructional practice, Conceptual change and Concept mapping, Professional development, Conceptual change & analogy, Nature of science & Socio-scientific issues, Reasoning skill & problem solving, Design based & urban education, and Attitude & gender. The category Conceptual change & concept mapping was clearly the most frequent covering some 40% of the papers in these nine categories. The next largest categories were Professional development, Conceptual change & analogy, and Nature of science & socio-scientific issues, which covered about 35% of the papers. It is, however, not straightforward to interpret these results because of the automatic mapping of keywords into the categories. The other results in the paper concerned author data, which are not relevant here.

Önder et al. (2013) surveyed 46 physics education papers in the Turkish *Science Education Journal* published 2004–2011, analysing them from many different points of view, including general themes and physics topics, author data and several aspects of the research process. The general themes (“what” aspect) included Learning approaches, Misconceptions and learning difficulties, Affective domain and skills, Measurement and evaluation, Material development and evaluation, Factors affecting the success, Usage of technology, Teacher education, Learning environment, Effects of Gender, Modelling and Other. The first three of these were most common and covered well over half of the papers.

Other work surveying science education research has focussed on aspects other than the topic of research. Rennie (1998) and Eybe and Schmidt (2010) discussed quality issues in reporting research in science education and chemistry education research, respectively. White (1997) analysed research methods in science education papers published 1975–1995.

We also looked at surveys of the “what” aspect in some neighbouring fields. In computing education research, Simon (2007) presented an elaborated categorisation scheme, which covers the “what” aspect in two dimensions, i.e., curricular context (subject domain), and the theme of the research (e.g. student’s understandings or educational technology). The system has been used to categorise over 600 computing education research papers (see Simon, 2009, and references therein). Joy et al. (2011) analysed 3500+ papers in 21 journals and 21 conferences in the areas of computing education, educational technology, and distance education. They presented their own categorisation scheme seeking to identify where to publish certain kind of work. Their results build a fairly comprehensive picture

of the different profiles of the journal/conferences. For example, they identify venues which focus on publishing technology papers, theoretically grounded pedagogical work or more practice oriented pedagogical work or curriculum issues.

In engineering education research (EER), several authors have investigated the “what” aspect. Wankat (1999, 2004), Osorio and Osorio (2002), Whitin and Sheppard (2004) surveyed research topics of the papers. The first two of these works also studied author data of the publications. Citation data has been investigated by Wankat (1999, 2004) as well as Wankat, Williams and Neto (2014).

As the purpose of the current paper is not comparing results between science education research and other fields, we do not discuss these works in more detail. However, we emphasise that *all* the studies mentioned above have used a data driven approach, that is, the categories have emerged from existing data. Such a method is an adequate method to reveal *what* research is being published. In the next section we derive a theoretically grounded categorisation of the “what” aspect. With such a method, we hope to *reveal also gaps in published research*, i.e., categories presenting areas of investigation, which could be relevant for the field but where work has not been reported. We have not found any such theory-based categorisation system in science education research or its neighbour fields. We have already used our method to reveal widely and less covered areas in some computing education research and engineering education research forums, as well as in science education papers published in Finland (Kinnunen, Meisalo, & Malmi, 2010; Kinnunen & Malmi, 2013; Kinnunen, Lampiselkä, Malmi, & Meisalo, 2013). We present the system in the next section and apply it to analyse papers published in the NorDiNa journal in Sections 4–6.

3. INTRODUCING MULTILAYERED DIDACTIC STRUCTURE

The typology we use is based on extending the didactic triangle, as presented by Kansanen and Meri (1999), and later extended by Kinnunen (2009) (Figure 1). The triangle presents the relations of three main aspects in the instructional process, the teacher, the student, and the content to be learned. The learning process takes place between the student and the content, and teacher’s pedagogical actions (A) modify/scaffold the process.

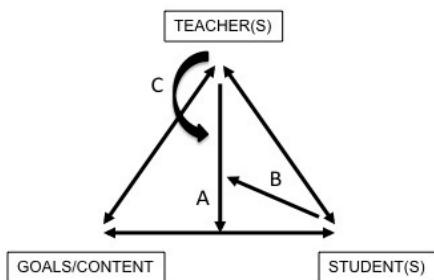


Figure 1 An extended didactic triangle (Kansanen & Meri, 1999; Kinnunen, 2009)

Kinnunen (2009) augmented the triangle to better present the richness of the instructional process. She introduced the relation between students and the pedagogical activities, which includes, for example, students’ experience of pedagogical activities and feedback on them (arrow B). Kinnunen et al. (2013) augmented the triangle even more. It is obvious that not only students have a relation on the pedagogical actions. Also teachers reflect on their work, which we present by adding another arrow (C), as follows.

Another development concerns the contextual extent of the triangle (Kinnunen, 2009), which can be presented by using different levels of analogous triangles. The original triangle presented the relation between the teacher, student(s) and content within a course context (course level). However, similar types of relations exist across teaching organisations, students studying in some degree programs and the goals/contents of whole curricula (organisation level). The pedagogical actions of the organisation influence the students' learning processes during their degree studies, and students as a whole can reflect on these actions. Furthermore, similar relations exist in society, in an even wider scale, between the educational organisations of the whole society, citizens and the general goals of education (society level). Finally, teaching and learning phenomena can also be discussed in an international context (international level), as some pedagogical actions, such as PISA evaluation studies, are operated as international activities (Kinnunen, Lampiselkä, Malmi, & Meisalo, 2014). We can present multiple levels of the didactic triangle, as follows (Figure 2).

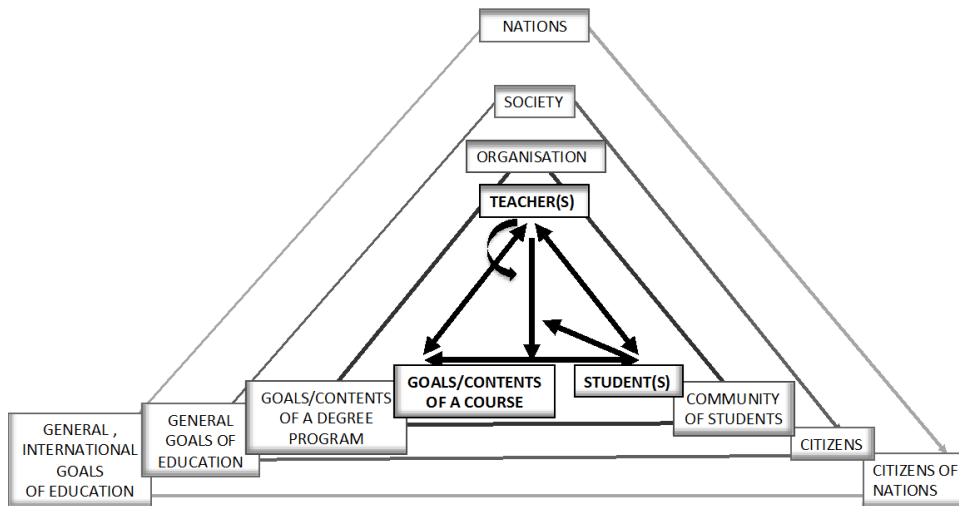


Figure 2 Multi-level didactic model based on the didactic triangle: course¹, teaching organisation, society, and international levels.

Our typology identifies research in eight main categories, and several subcategories within them (Table 1). Here we do not go in depth concerning the development of the categories since it has been documented in detail in our previous work (see e.g., Kinnunen, 2009; Kinnunen et al., 2014). Three categories derive from the nodes of the triangle (Figure 3): *goals and contents* (category 1), *students* (category 2), and *teachers* (category 3). Five categories derive from the connecting arrows: *relation between students and teachers* (category 4), *relation between students and goals & contents* (category 5), *relation between teachers and goals & contents* (category 6), *teachers' didactic actions*² (category 7), and *relation between students and teachers' didactic actions* (category 8). Categories 5 and 7 have been further divided into subcategories to better separate different forms how the relations may manifest themselves; for example category 7 includes types of assessment. All of the categories are applicable in different levels: *course*, *organisation*, *society*, and *international*. We have applied the original categorisation system in several contexts, to analyse computing education research papers (Kinnunen, 2009; Kinnunen et al., 2010), engineering education research papers (Kinnunen & Malmi, 2013), and science education papers (Kinnunen et al., 2013, 2014). In this study

¹ The course level consists of interactions between the teacher, students and the goals/content.

² Actions that forward attaining the goals.

we added the context, which is *educational level*, though this is not visible in the triangle, where we identify papers focusing on primary, secondary and tertiary education (including teacher training) or some combination of them.

Table 1 List of categories and their definitions. The number of the categories correspond to the numbers of the nodes/arrows in Figure 3. Note that each category operates at four levels: course, teaching organisation, society, and international levels.

Category name	Definition
1. Goals and contents	The goals and/or contents of a course, study module, goals of a degree program, society or international goals for education.
2. Student(s)	The characteristics (e.g. gender, level of education) of students' or community of students or citizens or citizens of several countries.
3. Teacher(s)	The characteristics of teachers, the teaching organisation, the society or the international level of educational bodies.
4. Relation between categories students and teachers	How the students perceive the teachers (e.g., studies on how competent students think the teacher is). Similarly, the papers, which focus on how teachers perceive students belong also to this category.
5.1 The understanding of and attitude about goals and contents by the student(s)	How students understand a central concept at the course or how interesting students/possible future students find the topic/degree program/certain occupation.
5.2 The actions (e.g. studying) the student(s) do to achieve the goals	Students' actions include all actions/lack of actions that are in relation to learning and achieving the goals.
5.3 The results of the action of the student(s)	The outcome of the studying process. E.g., studies that discuss the learning outcomes after using a new teaching method would be placed into this category.
6. Relation between teacher(s) and goals and contents	How teachers understand, perceive or value different aspects of the goals and contents.
7.1 The conceptions of teacher(s) of students' understanding of/attitude to goals/contents.	How teachers think about students' perceptions and attitudes towards goals and content. E.g., studies on what kind of knowledge teachers have on students' understanding of some central concept/process.
7.2 The conceptions of teacher(s) of students' actions towards achieving goals	Teachers' perceptions of the students' actions (e.g. studying).
7.3 Didactic activities of teacher(s)	The teachers' didactic actions (e.g. lecturing, providing a learning environment, assessment methods)
7.4 Teacher's reflections on his/her own didactic actions	E.g., to what degree teacher thinks the new teaching method was successful.
8. Relation between student(s) and teacher's didactic means to enhance learning	How the students feel about the teachers' didactic actions (e.g. course feedback)

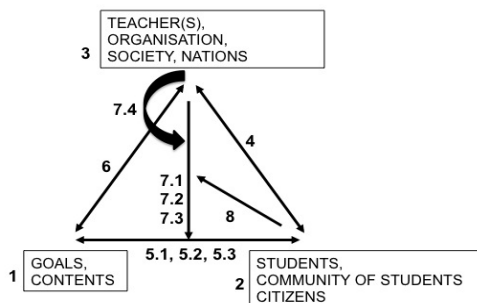


Figure 3 The categories placed on the didactic triangle

This extended multi-layered didactic structure allows us to build a broad picture of science education research: how widely different aspects of instructional processes have been covered in current research, as well as how widely they have been covered in different educational levels. This is a point of view that has not been covered by any of the previous classifications of research papers. Moreover, all previous typologies have been developed as data driven; thus they can reveal only those aspects found in the data. Our approach allows us to reveal aspects of research, which the theoretical framework suggests, but which have not been researched and thus provides guidance for future research.

4. SELECTION OF PAPERS AND ANALYSIS PROCEDURE

We chose to analyse the papers published in the Nordic journal NorDiNa over the period 2005–2013. NorDiNa is a peer reviewed international journal, which publishes high quality research papers written by authors mainly based in the Nordic countries. Therefore we have confidence that the papers reflect to some extent the trends in science education research in the Nordic regions. We delimited our data pool to physics and chemistry papers based on our own professional interests and the expertise of our research team.

Altogether 138 papers have been published in NorDiNa in 2005–2013. First we left out six papers written by authors from outside the Nordic countries (we did analyse these six papers but excluded them from the results). We also left out 43 papers relating to other science education fields and papers, which did not report on research. The 43 papers we left out of our study related mainly to biology education ($n=24$), technology education ($n=5$), or geography education ($n=2$). The rest of the papers discussed health education related topics, curriculum issues at a more general level, or introductions to a research/project plan. Finally we were left with 89 papers that reported a physics or chemistry education related study.

The analysis started by each author of this paper individually reading the papers. We read the whole paper trying to form a comprehensive overview of the paper and then made tentative notes on which category or categories applied to the paper and also made notes on the educational level. The final decisions were made in group meetings where all the authors came together to discuss each paper individually. During these meetings each researcher argued why the paper should be placed into certain category or categories. We discussed the paper until we reached consensus and had clear arguments why the paper belongs to one or several categories and not to some other. Therefore, we could describe the analysis process as being dialogical and heuristic by nature.

For instance, the paper by Håland (2010) reports on a study on student teachers' perceptions on evaporation and dew formation. Data was collected from 30 students enrolled in an introductory chemistry course at the university. This paper looked at students' understanding of a phenomenon

before the course. Therefore the paper was placed in category 5.1 (see Table 1), course level, educational level: university. The paper by Kleparker, Fläsen Almendingen, and Tveita (2007) looked at how teaching activities (category 7.3) influence students' attitudes towards science (category 5.1) and towards their teacher (category 4), and students' performance (5.3). The study also looked at which teaching activities students prefer (category 8). All aspects were presented in the study with equal weight. The data was collected from a large random sample of the total population of Norwegian upper secondary students thus indicating that the study is related to society level and the educational level is upper secondary school.

5. QUALITY DISCUSSION

5.1 Paper selection

The generalisability of our results relates partly to selection of analysed data. The results are based on one publication venue only. NorDiNa, like all the other scientific journals, has its own profile and acceptance criteria. For instance, based on our data it seems that studies that discuss international science education related issues are published mainly in other journals. In addition, it is quite natural that researchers often publish their research reports in several different venues. Therefore, we need to be careful to draw any far-reaching conclusions on the state and trends concerning all physics and chemistry education researchers in Nordic countries.

5.2 Analysis

To ensure that we based our categorisation decisions on comprehensive understanding of the paper we decided to read the whole paper before categorising it. Even though this procedure took more time than reading only, for instance, abstract and research questions we felt that reading the whole paper was essential in getting a comprehensive understanding of the paper. This decision was further backed up by our notions that in some papers the abstract and/or research questions did not reflect fully what had been reported in the rest of the paper. We also based our analysis on what authors had explicitly written rather than what we in some cases thought we were able to read between the lines as being the authors' intentions³.

The typology we use in this study is based on extended didactic triangle, which poses some limitations to what aspects the analysis is able to capture. The didactic triangle and its extensions portray different aspects of formal instructional processes. However, some other aspects, such as informal education, are out of the scope of this framework.

5.3 Interpreting categories

The categories are based on the developed version of the didactic triangle, which portrays the interwoven and concurrently active aspects of the instructional process. The categories we have derived from the multi-layered didactic structure are inherently overlapping. We strongly believe that joint discussions about each paper were essential in deciding which aspects of the instructional process the paper emphasised. We also recognise that this decision always includes somewhat subjective interpretation. This was the main reason why we ended up making the final decision on the categorisation only after joint discussions. This procedure ensured that the decision was not based on a single person's first impression of the paper but on a well-argued joint discussion. Also the decision on whether an emphasis was strong enough to be included in the results was made based on the comprehensive discussions on the paper. Because of the dialogical and heuristic nature of the analysis we did not see a meaning in calculating an inter-rater reliability.

³ The papers in NorDiNa are written either in English, Swedish, Norwegian, or Danish. Therefore, some papers were written in a language, which is none of the authors' mother tongue. Consequently, we may have missed some of the texts' nuances. However, a good command of English and Swedish and access to a reliable dictionary helped us to understand also the papers written in Norwegian and Danish.

Researcher triangulation was an essential part of our analysis process. Our research group consisted of experts from physics education, chemistry education, computer science education, and educational science. All researchers were experienced teachers and researchers and had previous experience in categorisation of research publications using the didactic focus based categories. Some of the researchers had additional experience in developing and using other types of categorisation systems. The variety of researchers' background was a definite strength when analysing the papers; differing backgrounds ensured that we discussed the papers from different viewpoints.

6. RESULTS

6.1 On which aspects of the teaching and learning process have physics and chemistry education publications in NorDiNa focussed? With what frequency are teaching and learning process related aspects studied? What aspects are much studied and what aspects are under-researched in NorDiNa

We found altogether 171 pedagogical foci distributed over 89 papers. On average papers had 1.9 foci (min=1, max=5, SD=1.0). The distribution of foci between different teaching and learning related aspects is summarised in Figure 4 and more detailed distribution between subcategories and levels is described in Table 2. By far the most publications report on studies that were done at the teaching organisation level (eighty eight foci distributed over forty six papers). Studies that were done at a course/classroom level were also frequent (forty four foci distributed over twenty papers). However, there were only some studies at a society level (thirty foci distributed over eighteen papers) and a few studies that discussed the pedagogical phenomena at the international level (nine foci distributed over five papers).

Goals and contents were studied rather often (category 1), whereas researchers' interests in student and teacher related aspects varied. Students' perceptions and their attitudes towards the content and goals (category 5.1), students' actions to achieve the goals (category 5.2), and their learning outcomes (category 5.3) were frequently studied. At the same time students' characteristics (category 2) and students' perceptions and opinions on interventions (category 8) were less frequently studied. When teaching methods were studied (category 7.3), these typically focused on the substance (category 1) or on the student–content relationship (categories 5.1–5.3). Other popular combinations of foci were teacher's teaching methods (category 7.3) and teachers' (category 7.4) or students' reflections (category 8) to these teaching methods, but research papers of this kind were rare when compared to the previously mentioned combination, i.e., 7.3, 1, 5.1–5.3.

Teachers' characteristics (category 3), teachers' perceptions/opinions/understanding of the goals and contents (category 6), teachers' perceptions of students' understanding of the goals and/or contents (category 7.1), and teachers' perceptions of students' actions towards achieving the goals (category 7.2) were studied much less. Students' and teachers' perceptions of each other (category 4) were also less studied aspects of the instructional process.

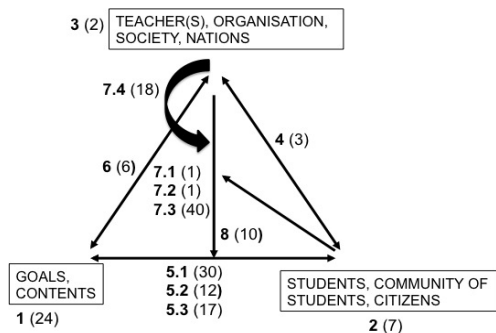


Figure 4 Distribution of foci to different categories. The category number is expressed in bold font, the number of foci placed in the particular category is expressed in the parentheses.

Table 2 Distribution of didactic foci into different categories. Percentages indicate in how many of the N=89 papers the category was identified.

Category	Course	Organi- sation	Society	Inter- national	Total	% of papers
1	1	10	11	2	24	27%
2	1	3	2	1	7	8%
3		2			2	2%
4	1	1	1		3	3%
5.1	8	15	6	1	30	34%
5.2	6	6			12	14%
5.3	10	2	2	3	17	19%
6		6			6	7%
7.1		1			1	1%
7.2	1				1	1%
7.3	12	20	7	1	40	45%
7.4	2	16			18	11%
8	2	6	1	1	10	11%
Total	44	88	30	9	171	

6.2 Which educational levels does physics and chemistry education research published in the NorDiNa focus on?

Studies that discussed lower and/or upper secondary school level issues were the most frequent in the data (Table 3). Studies that were done on the university level were also frequent ($n=22$). Nearly half of the university level papers related to teacher education. In many cases studies addressed more than one educational level, for instance, primary and lower secondary school education or lower and upper secondary school education.

Table 3 Educational levels of studies

Educational level	n	n studies that focused only on this educational level
Early childhood education (~under 6/7 years old)	2	
Primary school (grades 1 to ~ 6)	28	6
Lower secondary school (grades 7 to ~ 9)	43	17
Upper secondary school (grades 10 to ~ 12)	33	16
University	22	19
Working life	1	1

6.3 What differences are there in the focus of NorDiNa researchers in the different Nordic countries?

There were altogether 189 authors contributing to the 89 papers we analysed in this study. On average papers had 2.1 authors (min=1, max=6, mode=1, SD=1.2). Authors from Sweden were most active publishing their work in NorDiNa (Table 4), but authors from Norway have been more active if publishing activity is weighted against the population in these countries. Most papers were written with colleagues from the same country. Only 7% ($n=6$) of the papers were written in international collaboration.

Table 4 The absolute (n) and relative numbers (n_w) of research papers produced in each country. The country is determined based on the first author affiliation. The relative numbers are calculated by comparing the frequency against the most populous country (Sweden.) (Populations used in calculations (millions): Denmark 5.6, Finland 5.5, Norway 5.0, Sweden 9.6).

	Absolute	Absolute	Population weighted	Population weighted
	n	%	n_w	%
Denmark	8	7	14	11 %
Finland	13	13	23	17 %
Norway	29	30	56	43 %
Sweden	39	38	39	30 %
Total	89	100		

In general, we could notice some national similarities in trends in science education research. Research on students' understanding and attitudes (category 5.1), on results on students' actions (category 5.3) and on teachers' pedagogical actions (category 7.3) seem to be themes that interest NorDiNa authors in all Nordic countries. However, more interesting is that Table 5 also shows the aspects of the instructional process that are overlooked within these countries. There were only few studies on teachers' conceptions of students' understanding about the goals and contents of the course (category 7.1) or their actions towards achieving the goals (category 7.2). If we sum up the figures in Table 5, the finding shows that the publications in NorDiNa have focused mainly on the classical interaction between the teacher and the learner, in other words on what most people would prefer to call "teaching".

Table 5 Distribution of research papers in different categories in each country. The country is determined based on the first author's affiliation.

Category	Denmark	Finland	Norway	Sweden
1	14% (2)	17% (4)	12% (12)	7% (6)
2		4% (1)	6% (3)	4% (3)
3	14% (2)			
4		4% (1)	4% (2)	
5.1	14% (2)	21% (5)	19% (10)	16% (13)
5.2		4% (1)	6% (3)	10% (8)
5.3	7% (1)	13% (3)	8% (4)	11% (9)
6	14% (2)	4% (1)		4% (3)
7.1				1% (1)
7.2				1% (1)
7.3	29% (4)	29 (7)	12% (12)	21% (17)
7.4	7% (1)	4% (1)	6% (3)	16% (13)
8			6% (3)	9% (7)

Many aspects of the teaching–learning process have been investigated in all countries, and naturally the more research is done the more versatile the research becomes and more aspects of the teaching–learning process can be covered. This appears best in Sweden, where research covers nearly all categories. Research in Denmark, Finland and Norway has not been as diverse, and the studies have focused on the most expected areas, students' attitudes and content learning (category 5.1 and 5.3) and teachers' teaching of the content (category 7.3). We could find some national trends that differentiate the countries. Finnish, Danish, and Norwegian researchers have been interested in the goals and the content issues (category 1) more frequently than Swedish researchers. Moreover, Danish researchers have paid relatively more interest to teachers (category 3) and the Swedish researchers to teachers' reflection (category 7.4).

More similarities and differences among the Nordic countries can be found if we take a closer look at the levels of the research (Table 6). Finnish researchers have paid most interest to course level studies

whereas the Swedish, Norwegian and Danish researchers to organisational level studies. Danish and Norwegian researchers have been active in society level studies too, whereas Finnish and Swedish have not been so active. International level studies are most frequent in the Norwegian research publications. In general, it seems that studies that are a bit more local with a practical orientation of the study design are more typical in Finland and Sweden than Norway and Denmark.

Table 6 Distribution of research foci in different levels in each country

Level	Denmark	Finland	Norway	Sweden
Course		46% (6)	13% (4)	26% (10)
Organisation	50% (4)	31% (4)	47% (14)	62% (24)
Society	50% (4)	15% (2)	30% (9)	10% (4)
International		8% (1)	10% (3)	3% (1)

7. DISCUSSION

7.1 Much studied aspects of teaching and learning process

The data pool of this study consists mainly of studies done on the secondary or tertiary level of education and therefore content oriented studies, such as mastering the content, attitudes towards the content, or views about the teaching of the content, were frequent. On the primary level of education, the educational emphasis is a bit more on the general educational and the pupils' personal growth tasks than on the content learning task. Content learning begins to be a more important educational task from the lower secondary level onwards.

On the other hand, the popularity of the content oriented research and the content-method combination among the studies could be some sort of consequence of the researchers' educational background as well. The secondary and tertiary level teachers and the researchers in the higher-level institutions have subject-oriented backgrounds, and it is only natural that they are more interested in the subject itself than general issues. Moreover, the national curriculum and the school textbooks describe rather explicitly what contents are to be taught, whereas teaching methods are not so well described in these documents. Therefore, it is expected that research interest is directed on how to teach the content in such way that learner can understand it correctly.

Nevertheless, we are a bit worried about the relatively small portion of studies published that focus on reflection and how the teachers and the learners see the meaningfulness of classroom practices. However, we do not want to put too much emphasis on this gap because some attitude, motivation, or interest studies did embrace the topic and give insight to the reflection component of the teaching-learning process, too. Society level studies are more frequent in category 1 (goals and contents) than in any other category. This is easily explained by the fact that category 1 includes curriculum studies, which self-evidently have a national level orientation.

7.2 Aspects of teaching and learning process less studied

The results suggest that there is low number of studies on teachers. Studies on teachers' characteristics, their perceptions/opinions/understanding of contents and goals or perceptions of students' understanding of the content and/or goals, as well as teachers' perceptions of students' actions towards achieving the goals, were rare. Neither were teachers' perceptions of students a popular research focus.

A teacher has a central role in the teaching–studying–learning process and should have also a key role in educational research. We could not find any particular reasons for the absence of teacher-oriented studies, but a few tentative explanations are given. Perhaps, the publicity of the school education as such sustains the good quality of teaching, good working environment, and job satisfaction. If the teachers are unsatisfied with their work or, for example, if their teaching methods are out of the date, it would be soon reported in a newspaper, or in teachers' association publication or in other relevant educational media. Also, the schools, the parents, and the educational authorities are in close cooperation all the time and poor school conditions or poor school management would easily exceed the threshold for news and lead to renovations. The teachers are well educated and they learn the basic means and methods how to develop one's own work and how to maintain job satisfaction in the teacher education. The teachers participate in continuing education and sustain their professional growth during their whole careers, which help them to keep up the motivation in their work. However, some researchers propose an idea that teachers do not want to be studied. This might be true in some cases, but we cannot give any hard evidence on the validity and reliability of these kinds of considerations. On the contrary, we claim that teachers' reflections are studied frequently, but these are more or less some sort of small-scale opinion polls that are carried out on school or municipal level. These polls do not reach the quality that is required from an academic research and therefore do not exceed the threshold of an academic publication, but serve well the local school or municipal needs. The other reason might be as well the fact that studies about teachers or their reflections are published in general education journals and therefore do not appear in our data pool. Nevertheless, even though data was not particularly extensive, it became rather evident that "the teacher" in its manifold manner seems to be one of our blind spots. Studies about teachers' reflections of their work could yield important information on how they see the meaningfulness of classroom practices.

7.3 Educational level

We observe that in NorDiNa papers there is relatively little research on science education in lower grades. One interpretation might be that this research could be reported on in other forums. Another reason is obviously that, at least in Finland, lower grades science education has been focussing earlier on biological sciences while physics and chemistry topics have not been included in the framework curriculum of the elementary school and thus there has been little to study as practically nothing was taught.

7.4 Course/organisation/society/international level

In our data pool there is obviously a dearth of society level studies. A few explanations can be given why the majority of the studies are in courses and organisational levels and minority in societal and international levels. First, it is typical for educational research that in the first place it aims at improvement of the teaching and learning environment in the local community rather than in the national frame. Also, a study comprising only a few classrooms is rather easy to organise and get funded. In order to collect appropriate data for a society level study one needs national or at least the municipal scale survey. Data collection and data analysis in this scale is expensive and therefore research projects are rare and consequently infrequently reported. Moreover, when a large-scale study is launched, it might be divided into smaller local scale research projects, in turn increasing the number of course and organisational level studies.

However, it is plausible, that society level studies are not as rare as our data show. Instead we assume that society level studies are rather frequent too, but they are reported elsewhere like in Scandinavian, European or international journals to reach as wide an audience as possible. In this study, the data is collected from a journal of which the target audience is rather restricted (Nordic area). Society level studies also have potential for international level discussions, but this was seldom taken. There is a large difference in having plenty of exchange of opinions on the outcomes of international compara-

tive studies like PISA and focusing research on international problems. Anyway, this lack of international level discussion in NorDiNa is something to consider seriously in our opinion.

7.5 Differences between countries

The Finnish and the Norwegian researchers' interest towards the goals and content issues might be explained by the development of national curricula just before or during the timeframe 2005–2013, but we could not find a similar single reason for the interest of Danish researchers in this context. Also, we could not suggest one single reason why teachers' reflections have been studied in Sweden so much more than in the other countries. One tentative reason could be that there have been a few active research groups that have been interested in studying the particular issue and these groups have been active in reporting their studies too. The Danish researchers' exceptional interest in the teachers themselves could be interpreted by a statistical anomaly. The number of research papers published by Danish researchers is relatively low and consequently just a few hits in the list produce relatively high proportions.

7.6 Comparison with previous studies in science education research

None of the previous categorisations of research content ("what" aspect) is fully compatible with our categorisation system. There is, however, considerable overlap, which allows us to make some comparison of results.

In the works of Tsai and Wen (2005) and Lee et al. (2009) the largest categories were *Learning-Conception* ("Methods for investigating student understanding; students' alternative conceptions; instructional approaches for conceptual change; conceptual change in learners; conceptual development.") which included 24.7% of papers in 1998–2002 and 15.3% of papers in 2003–2007, and *Learning-Contexts* ("Student motivation; learning environment; individual differences; reasoning; learning approaches; exceptionality; teacher–student interactions; peer interactions; laboratory environments; affective dimensions of science learning; cooperative learning; language, writing and discourse in learning; social, political, and economic factors."), including 17.9% of papers in 1998–2002 and 23.5% of papers in 2003–2007. The former mostly corresponds to our categories 5.1–5.3 and 7.3 and the latter overlaps with categories 2, 4, 5.2, and 7.3. Our findings where the largest categories were 5.1 (students' understandings and attitudes, 33.7%) and 7.3 (pedagogical actions, 44.9%) match with their results. Important categories were also our category 1 (goals/content, 27%) and their category *Goals and Policy* (Curriculum, Evaluation, and Assessment. Curriculum development, change, implementation, dissemination and evaluation; social analysis of curriculum; alternative forms of assessment; teacher evaluation; educational measurement; identifying effective schools; curriculum policy and reform) which included 13.6% of papers in 1998–2002 and 12.7% in 2003–2007.

There were also clear differences. We found very few papers in category 3 (teachers, 2.2%), while Tsai and Wen (2005) and Lee et al. (2009) had identified considerable share of papers in the category Teaching ("Teacher cognition; pedagogical knowledge and pedagogical content knowledge; forms of knowledge representation; exemplary teachers; teacher thinking; teaching behaviours and strategies.") while they found in 6.9% of such papers in 1998–2002 and 13.9% in 2003–2007. This may reflect differences in the autonomy and status of teachers in different countries. Moreover, studies in category 2 (students, 7.9%) were also few in our data pool while in their work the category *Cultural, Social and Gender Issues* (Multicultural and bilingual issues; ethnic issues; gender issues; comparative studies; issues of diversity related to science teaching and learning) was larger, including 14.3% of papers in 1998–2002 and 6.8% in 2003–2007. This may reflect that gender and ethnic issues have been more important in international settings than among NorDiNa authors, at least earlier.

Other categories of Tsai and Wen (2005) and Lee et al. (2009) (Teacher Education, Philosophy, History, and Nature of Science, Educational Technology, and Informal Learning) are difficult to match

with our system. Moreover, we must note that in their work they counted each paper only once in each category, while in our work a paper could belong to several categories. This explains the larger percentages in our work.

In the later study by Tsai, Wu et al. (2011), which focussed on studies on science learning in Asia in 2000–2009, we find some interesting comparisons. This time, the categorisation principles are comparable (a paper could belong to several categories in both systems). The most common categories in their work were very popular: *Learning-Conceptions* (54.8%) and *Learning-Contexts* (68%) were clearly more popular than ours. *Goals and Policy* papers were more common than in the large data set (17.5%) but still less than in our results. Teaching category included 7.5% of papers (with us 2.2%), and *Cultural, Social and Gender Issues* included even 23.3% of papers (with us 7.9%).

8. CONCLUSION

The typology based on extended multilevel didactic structure was designed to help us to build a holistic picture of educational research: and investigate to what degree different aspects of the teaching–studying–learning related processes have been studied in NorDiNa publications. All earlier categorisation approaches have been developed as data driven; thus they bring up only such aspects of research that can be found in the data. The present approach allows identifying aspects of research, which the theoretical framework suggests, but which have not been studied and thus provides potential for future research. Altogether, the holistic coverage of the educational process is the strength of our approach. It provides a view of the data that would be difficult to get otherwise. And it provides ideas about possible good new research topics. We conclude that the categorisation system used in this paper works well. It is important however to have experienced researchers with wide competence profiles for reliable categorisation. This kind of analysis has a potential to provide a holistic view of science education research and is valuable both for young and experienced researchers.

We may now ask, at what kind of a future we are aiming? We want to provide a method for identifying areas in need of further research, which could yield solutions to problems of science education. We feel that we have now proved the usefulness of our approach in analysing papers on physics and chemistry education. Next we are planning to include biological and environmental education papers in our research area, as a related expert is joining our team. We shall also consider widening our data pool from Nordic to European and global perspectives.

Finally, what we can say about the research profile of Nordic authors who have published in NorDiNa – what does it look like? Our limited data set provides indications of which might be more and which less studied areas among Nordic researchers and further studies with wider data pool are needed before drawing any definite conclusions. However, based on our results we want to draw attention to topics that have been published less often in NorDiNa and give two suggestions for special issue topics:

- Science teachers: for instance, teachers' characteristics, their perceptions/opinions/understanding and reflections on the meaningfulness of classroom practices.
- Studies that discuss teaching and learning related issues at society and international levels. Knowledge of teachers' way of understanding and perceiving educational phenomena – information that would be highly relevant for instance, for teacher education and further education providers. Emphasis on society and international level studies would enable us to discuss the impact and relevance of local educational structures and environments on learning outcomes.

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