Informatics as a common fundamental competence at all educational levels

This special issue of Acta Didactica Norden is about informatics as a common fundamental competence at all educational levels. The target group is school-teachers, teachers at teacher education colleges and universities, informatics education researchers and everyone else with a special interest in informatics education in the entire educational system.

The nine articles in this special issue give an impression of the state-of-the-art of informatics education research in the Nordic countries, and we hope that the articles will inform and inspire practitioners as well as researchers to further develop and improve the state of this still emerging but important field in the Nordic countries. Globally, the field is flourishing.

Except for one, all articles are in English; we neither hope nor think this will diminish dissemination to Nordic practitioners and researchers; however, it improves the chances that Nordic research and culture in informatics education may transcend the Nordic community, as we firmly believe that the Nordic approach has important knowledge to offer to the international community.

During the submission process, we had indications of publications from several Nordic countries, but in the end, the nine articles are from two countries, Norway (4) and Denmark (5).

Informatics – an emerging school subject across Europe

Computational literacy, computational thinking, computing, digital skills, digital literacy, digital competences, informatics, information technology, IT, programming, coding, technology comprehension, and technology in praxis – these are just some of the terms flourishing in the Nordic countries at this time of upheaval of deep digital competences in general education – not just in the Nordic countries, but globally.

In Europe, ‘informatics’ is becoming the preferred designation of this new and emerging school topic (Eurydice, 2022), and we as editors prefer this term. There are several reasons for this.
In 2018, the Informatics for All coalition (2018) was created to advocate for the inclusion of informatics as a foundational discipline in schools across Europe – foundational just like reading, writing and mathematics (the foundational competences of the industrial area). The purpose of the coalition is to give due recognition to informatics as an essential foundational discipline for education in the twenty-first century as an important subject on its own but also essential to excel in all other subjects and disciplines.

In September 2020, The European Commission published a revised version of the Digital Education Action Plan for 2021–2027 (DEAP, 2020a), which has “enhancing digital skills and competences for the digital transformation” as one of two strategic priorities. DEAP distinguishes between basic digital skills (digital literacy) and deep digital competences, where the latter specifically prioritises “a focus on inclusive high-quality informatics education at all levels of education”. One of the goals of the DEAP (action 10) is to reach agreement on a coherent vision and shared terminology related to providing informatics to all students in Europe (DEAP, 2020b).

In February 2022, the Informatics for All coalition published the Informatics Reference Framework for School (Informatics for All, 2022) as a proposal for a coherent vision and shared terminology for informatics in school. The reference framework is not a curriculum but a higher-level description that provides a shared vision of the discipline while allowing each country to implement its own curriculum in a manner compatible with its history and tradition. “Unity in diversity” is the motto. To this end, the framework is intentionally concise and flexible. It lists only five competency goals that all students should achieve at the end of their compulsory schooling, paying attention also to the personal, social and societal aspects of digital technologies, a topic whose relevance is becoming more and more important.

From a Nordic perspective, it is reassuring that the European Informatics Reference Framework for School (Informatics for all, 2022) includes along with more traditional computing topics some of the more human-centred topics such as design, development, responsibility, and empowerment – in fact, all 11 core topic areas of the reference framework can almost one-to-one be found in the Danish curriculum for primary, lower and upper secondary education.

In September 2022, a Eurydice study on Informatics education at school in Europe (Eurydice, 2022) was published. The Eurydice report provides a comprehensive comparative analysis of informatics education as a distinct discipline in primary and general secondary education in 2020/2021 in 39 education systems. The report contributes to building a shared understanding of informatics in school education providing a comparative analysis of curricular approaches, learning outcomes and teachers’ qualifications and training in primary and secondary schools across Europe.
Background and the articles of the special issue

Not just in the Nordic countries and Europe but globally, informatics is making its way into general education. It is a major challenge first and foremost because informatics is a new discipline in general education, which none of us have learned – of course neither in primary nor in lower secondary education, but not even in upper secondary education where the subject is still only partially implemented (Eurydice, 2022). It is probably the first time in history a new subject is introduced in primary and lower secondary education at a global scale without a prior thorough foundation in upper secondary education. This calls for special care, thorough initiatives and proper education of schoolteachers and those educating schoolteachers.

The articles in this special issue address just a few of the challenges of including informatics in education. There are articles about informatics as a subject on its own or integrated into other subjects; there are articles on informatics in primary, lower and upper secondary as well as tertiary education, particularly informatics in teacher education.

This special issue about informatics as a general and fundamental competence at all educational levels consists of nine articles divided into five sections:

- **Section 1: Literature review**
  - Empowerment through computational thinking: A literature survey by Line Have Musaeus, Maarten Van Mechelen, Michael E. Caspersen and Ole Sejer Iversen

- **Section 2: Content and borders**
  - A solution to what? Aims and means of implementing informatics-related subjects in Denmark, Sweden, and England by Andreas Lindenskov Tamborg
  - Critical-aesthetic scenarios in technological comprehension – an interdisciplinary approach (Kritisk-aestetiske scenarier i teknologi-forståelse – en tværfaglig tilgang) by Morten Raahauge Philipps, Simon Skov Foug and Stine Ejsing-Duun (written in Danish)

- **Section 3: Programming in school and higher education**
  - Block-based programming and computational thinking in a collaborative setting: A case study of integrating programming into a maths subject by Renate Andersen
  - From programming to computational perspectives in higher educations for humanities students by Anders Kalsgaard Møller, Camilla Finsterbach Kaup, Eva Brooks, Dorina Gnaur, Maja Højslet Schürer, and Marie Charlotte Lyngbye

- **Section 4: Pre-service teacher education**
  - Learning to make and use computer simulations in science education by Siv Gundrosen Aalbergsjø
• Section 5: Informatics in mathematics
  o Programming in the mathematics classroom – Adversities students
    encounter by Morten Munthe
  o Mapping the relations between computational thinking and mathem-
    atics in terms of problem-solving by Camilla Finsterbach Kaup
  o Teachers’ understanding of programming and computational think-
    ing in primary education – A critical need for professional develop-
    ment by Reiar Kravik, Tonje Karoliussen Berg and Fazilat Siddiq

The first section consists of one article, Empowerment through computational
thinking: A literature survey by Line Have Musaeus, Maarten Van Mechelen,
Michael E. Caspersen and Ole Sejer Iversen. The authors present a literature
survey of the notion of ‘computational empowerment’. The starting point of the
article is the broad consensus that computational thinking (CT) should be inte-
grated into education, and that empowerment often is used as an argument for why
future generations need CT skills. The authors present a systematic literature
survey that categorises various strands of empowerment as they unfold in CT
education research by applying an existing categorisation tool that defines the use
of empowerment in relation to five interpretations: management, critical, demo-
ocratic, functional, and educational empowerment. Their analysis identifies several
important limitations in the current literature. First, ‘empowerment’ is frequently
used but seldom defined in current CT literature. Second, the understanding of
empowerment varies substantially depending on geographic region, which means
that empowerment as an end-goal in CT-related education may differ significantly
from region to region. Third, critical and management empowerment are under-
represented in the international CT literature but are more prevalent in research
carried out in the Nordic countries. The article concludes by suggesting a research
agenda to secure a more palpable research literature related to empowerment and
to support future research, and to support ongoing policymaking.

The second section consisting of two articles presents the content and borders
for informatics, also challenging the potential content of the field. The section
starts with A solution to what? Aims and means of implementing informatics-
related subjects in Denmark, Sweden, and England by Andreas Lindenskov
Tamborg. Based on policy borrowing, the article studies the political rationales of
curriculum revisions regarding informatics in Danish, Swedish, and English
compulsory school. The article further studies how these rationales are converted
into concrete curriculum revisions, and implementation strategies in the three
countries. Empirically, the article is based on policy documents, research papers,
and reports from the three nations and interviews with 10 experts who were part
of, or knowledgeable about, the implementation processes in the respective coun-
tries. The findings are that, in spite of all three countries targeting the inter-
ationally agreed-upon challenge of preparing students to participate in a digitised
society, the national policy aims vary substantially. In Denmark, the curriculum
revisions aimed to educate critical, democratic citizens. Revisions in England were related to a strong push from the IT industry and an aim to reclaim the historical role of being tech pioneers, and Sweden was oriented towards creating equal digital competencies across demographic and socioeconomic factors. Despite such relatively clear-cut political rationales, the article also finds that the initiatives launched to meet the rationales were highly nationally situated, and, to some extent, contingent. In that respect, the article argues that the policy revisions in all three countries rather are products of what was possible or mere chance than of painstaking planning.

This is followed by the third article – and the only one in a Nordic language (Danish) – *Critical-aesthetic scenarios in technological comprehension – an interdisciplinary approach* (Kritisk-aestetiske scenarier i teknologiforståelse – en tværfaglig tilgang) by Morten Raahauge Philipps, Simon Skov Fougt and Stine Ejsing-Duun. The article explores how critical-aesthetic scenarios can be used in courses that include all four spheres of competence to help develop the didactics of the Danish subject “technology comprehension”. The article hypothesises that such scenarios are well suited to support students’ digital empowerment through critical thinking due to the scenarios’ ability to allow students to leave their own point of view and critically consider the issue from multiple perspectives through processes involving work on materialisations of ideas concerning technology and the consequences of the use of technology. Inspired by design-based research, the study is based on a course in which sixth grade students developed digital artifacts that critically exhibit society’s use of health data. In the first part of the course, students designed a death clock predicting the date of a person’s death. In the second part, they designed a prototype for a health program addressing one of three scenarios: a totalitarian state, a hospital, or the students’ own business. Empirical data were collected through observations and interviews with the teacher and students, before being analysed with a focus on the potential learning potential, actualised learning potential, and actual learning. The analysis reveals extensive potential learning potential that is only actualised in the classroom to a limited degree, resulting in limited actual student learning. These findings are discussed in relation to the article’s theoretical perspective as well as experiences gathered from the national trial in order to qualify future lesson plans based on critical-aesthetic scenarios.

This leads to the third section, also consisting of two articles, which focus on programming in primary and lower secondary education as well as in higher education. *Block-based programming and computational thinking in a collaborative setting: A case study of integrating programming into a maths subject* by Renate Andersen states that these two areas have undergone a revival in K–12 education and addresses in what ways block-based programming can be integrated into a maths subject, and what the implications for CT are. The empirical data are derived from a design-based research project consisting of four interventions over a duration of two years. A total of 43 pupils aged 12–16 years participated in the
interventions and used MakeCode (a block-based programming language) with micro:bit to create solutions for maths tasks assigned by the teachers. The pupils met three hours per week for 16 weeks during two semesters, and data were collected using video recordings of Zoom meetings (due to the Corona pandemic). A thematic analysis was performed in the first rounds of analysing the data to complete an overview of the entire data set, screening for common topics. Subsequently, interaction analysis was used to analyse select parts of the data in detail. The main findings in this article are that integrating block-based programming into a maths subject enabled active and collaborative learning; integrating programming into a maths subject enabled the development of CT; and block-based programming facilitated learning of maths.

The fifth article, From programming to computational perspectives in higher educations for humanities students by Anders Kalsgaard Møller, Camilla Finsterbach Kaup, Eva Brooks, Dorina Gnaur, Maja Højslet Schüer, and Marie Charlotte Lyngbye, studies how students in a master’s program in IT at a humanities faculty developed skills in programming and computational thinking due to the increasing need for IT competencies; thus, university humanities programs have started introducing courses to strengthen students’ understanding of informatics. The students had a compulsory course in Programming and Prototyping, and some of the students also had electives in Computational Thinking. Data consisted of observations from the courses and assessment of the students’ assignments, and four focus group interviews (two groups – a Computational Thinking group and a Programming and Prototyping-only group). Interviews before and after the courses for both groups uncover how the students’ views changed. The students who took the electives in computational thinking showed a richer vocabulary when describing computational concepts, practices, and perspectives. The ability to reflect on the practical tasks, including concepts, practices, and perspectives, seems essential for students’ future careers, as humanity students working with technology. Both groups of students saw themselves in coordinating roles where they would collaborate with programmers and other software developers. The results show how students can develop their understanding of computational thinking through scaffolding for computational empowerment. In the process, the authors saw how students achieved a computational understanding through working with concepts and practices and where perspectives emerged from combining the computational understanding with information and practices from other disciplines.

The fourth section with one article focuses on preservice teacher education: Learning to make and use computer simulations in science education by Siv Gundrosen Aalbergsjø. She states that, with the inclusion of programming in the school curriculum, a need to educate teachers in this area has emerged. Pre-service teachers (PSTs) participated in a teaching module about programming simulations for use in science. The PSTs’ reflections about their learning process and the teaching plans they developed were analysed using the technological pedagogical
content knowledge (TPACK) framework with the aim to investigate their knowledge background and learning needs, as well as opportunities for teaching programming of computer simulations to PSTs. Developing technological knowledge was challenging but useful for the PSTs. They were able to combine this with pedagogical and science content knowledge to make teaching plans to promote learning of science, technology, and scientific inquiry, and modelling practices. Thus, exposing PSTs to programming in their teacher education is important for their TPACK development and contributes to their ability to plan science education using these tools.

The fifth and final section consists of three articles with a focus on informatics and mathematics. The seventh article, *Programming in the mathematics classroom – Adversities students encounter* by Morten Munthe, investigates the implementation of mathematical programming problems among upper secondary school students and the kinds of adversity they experience when working on such problems. The adversities are classified and analysed within a framework of four categories. Concept adversity refers to the use and knowledge of different commands and types in the programming language. Syntax adversity concerns the structure of conditions and loops and the logical build of a program. Output adversity occurs after pressing the ‘run the program’ button and receiving, for instance, syntax errors, unexpected answers, or no output, and coding adversity is encountered when converting a mathematical procedure to programming code. Alongside several excerpts from transcripts, each adversity is discussed in relation to both mathematical learning and how to mitigate undesirable adversities. Concept adversity was observed to have no relation to mathematical learning, while at the same time not impeding such learning significantly. Syntax and output adversity were observed to contribute to mathematical learning when students started exploring the problems but did not contribute to learning when they were unable to resolve the problem. Coding adversity, when resolved, was observed to facilitate exploration and learning.

The eighth article, *Mapping the relations between computational thinking and mathematics in terms of problem-solving* by Camilla Finsterbach Kaup, unfolds computational thinking in relation to mathematics due to its growing popularity in educational settings the last two decades. The study reviewed 19 papers published between 2014 and 2021 and provides new opportunities for understanding how to get involved and introduce computational thinking into mathematics teaching. It was found that computational thinking and mathematical thinking had a relationship and that problem-solving could be an approach to relating them. The findings reveal that the relationship is primarily theoretical and that teachers found it challenging to make a connection between computational thinking and mathematics. In addition to providing a structured example of research conducted in the field and identifying gaps, the study raises new research opportunities.
Finally, *Teachers’ understanding of programming and computational thinking in primary education – A critical need for professional development* by Reiar Kravik, Tonje Karoliussen Berg and Fazilat Siddiq addresses how programming and computational thinking have (re)gained an increased focus in compulsory education worldwide, consequently demanding teachers of various subjects to engage in the teaching and learning of the two. The recent curriculum reform in Norway emphasised the development of students’ computational skills by integrating programming into four subject domains: mathematics, natural science, music, and arts and crafts. However, these requirements come without the necessary professional development programme and are based on the presumption that all concerned teachers understand the concepts of programming and computational thinking and know how to teach these skills in a sound pedagogical and didactical way. Therefore, this study investigated how teachers understand programming and computational thinking and the relationship between the two concepts. The authors also investigated the teachers’ approaches to teaching these concepts and their need for further professional development, through semi-structured interviews with eight primary school teachers where data were analysed thematically. Overall, the teachers reported positive attitudes towards the new curriculum and its focus on 21st-century skills, including programming and computational thinking. However, their understanding of these concepts was narrow, focused on only one of the five pertinent sub-skills: algorithms. Furthermore, the teachers’ teaching approaches were limited. Finally, the authors observed a variety of professional development processes and practices. The teachers accentuated a critical need for professional development within these domains, showing that to fulfil the curricular expectations of developing students’ computational thinking skills, increased training of primary school teachers is needed.

About the editors

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References


