CURRICULUM DEVELOPMENT AND PROJECTS

Professor Jari Lavonen was the director of the Finnish Graduate School of Mathematics, Physics and Chemistry Education from 2007 until 2011. He is currently a professor of physics and chemistry education and the head of the Department of Teacher Education at the University of Helsinki.

Dr. Heidi Krzywacki earned her PhD degree from the Finnish Graduate School of Mathematics, Physics and Chemistry Education in 2009. In addition to her experience as a doctoral student, she had an active role in organising the activities and international collaboration of the graduate school. She works now as a senior lecturer in mathematics education at the Mälardalen University in Sweden.

JARI LAVONEN

Department of Teacher Education, University of Helsinki, Finland
jari.lavonen@helsinki.fi

HEIDI KRZYWACKI

The School of Education, Culture and Communication, Mälardalen University, Sweden
heidi.krzywacki@helsinki.fi

Recent trends in PhD education in science and mathematics education research: Back to university-level organisation

Abstract

This descriptive article aims to discuss the development of Finnish PhD education in science and mathematics education research over the past 20 years. First, the general aims and structure of PhD education at the national level are introduced. Doctoral studies seek to develop research knowledge and skills as well as the capability to produce novel scientific knowledge. Second, the development of PhD education in the Finnish context of science and mathematics education research is discussed. For the past 20 years, there has been a special focus on improving PhD education through national-level graduate schools and international collaboration. Finally, the recent changes in PhD education, such as the replacement of doctoral programmes at local universities, is discussed through the case of the University of Helsinki.

AIMS AND PRACTICES IN PHD EDUCATION

There are several ways to conceptualise and organise PhD education. The recent movement has placed the focus on multi-faceted aspects of doctoral education or educating PhD students not only for academic fields but also as experts in the non-academic labour market (Baschung, 2010). Another recent trend has been towards structured and clearly organised PhD education that aims to support the holistic nature of the learning process (e.g., Cumming, 2010). Many countries have developed systematically their PhD education system and introduced PhD education programmes, which include formal courses in methodology and subject matter as well as seminars, workshops, co-writing activities and codes of practice. These have had a positive influence on the submission of doctoral degrees in countries such as the United Kingdom (Humphrey, Marshall, & Leonardo, 2012). There are several reasons for developing PhD education, such as increasing the amount of doctoral degrees and

improving the quality of PhD education. According to Baschung (2010), the development of doctoral education has resulted in the internationalisation of PhD education due to cooperation between different countries and increasing competition for higher quality.

It is well known that supervision is a crucial part of the learning process during PhD education. The style of supervision and the relationship that the doctoral student and supervisors have make a difference (Gatfield, 2005). As Lee (2008) stated, supervision should also be conceptualised through aspects other than functional ones related to PhD project management. For example, both enculturation, which refers to encouraging PhD students to become members of the disciplinary community, and developing a quality relationship that inspires and supports the student are considered essential (cf. Pyhältö, Stubb, & Lonka, 2009). According to Cumming (2010), it is not possible to reach a broader and more holistic view of the research field if PhD education is approached through a rigid view of inputs and outputs during the PhD study process. He suggested crossing the boundaries between education, training, research, work and career development. Furthermore, well-organised quality assurance and quality enhancement help improve PhD education.

PhD education in Finnish universities has gone through several changes in the past decades. The latest development is that, since 2012, national resources have been allocated directly to individual universities for organising their own doctoral programmes, instead of national-level graduate schools, which were established in the mid-1990s (see Önnersfors, 2007). Thus, each university is responsible for the organisation, quality and development of PhD education. This organisational change is expected to result in the improvement of the quality of PhD education in aspects such as student recruitment and selection as well as cooperation within the scientific community. However, moving back to PhD education organised within individual universities causes special challenges for developing and supporting research on subject-specific issues. It raises doubts of the future of collaborative PhD education with a special focus on science and mathematics education.

The aim of this article is to discuss the development of Finnish PhD education in science and mathematics education research over the past 20 years. We start by describing the general aims and structure of PhD education at the national level. Thereafter, we discuss the development of PhD education. The last part of this article focuses on the recent trends in Finnish PhD education by describing the recent progress of the University of Helsinki as an example. The paper is based on a presentation given by the first author at the conference “Graduate and Postgraduate Programs in Education in Arab Universities: Quality and Added Value”, which was held at the Lebanese American University (LAU) in Beirut in November 2013. The first author was the director of the Finnish Graduate School for Research in Science and Mathematics Education from 2007 to 2011. The second author was a PhD student in the graduate school from 2003 until 2009 and was partly responsible for organising 11 international training seminars in which the Finnish Graduate School was involved.

AN OVERVIEW OF PHD EDUCATION IN EDUCATIONAL SCIENCES IN FINLAND

Finnish universities have a long tradition of PhD education in the educational sciences that is rooted in the 18th century. However, formal PhD education started only in the 1950s (Husso, 2005). The faculties of Finnish universities are responsible for organising doctoral studies (Ministry of Education, 2000). Since the 1960s, the general aim of doctoral studies has been to develop students’ in-depth knowledge of research and their capability to produce novel scientific knowledge independently. In practice, those who have completed a master’s degree in a discipline, including a master’s thesis, are considered post-graduate applicants. The application is mainly composed of a well-written research and study plan that is initially discussed and prepared with the help of prospective supervisors. The application is accepted by the faculty council based on the evaluation by the main supervisor; nowadays, evaluation by a research affairs committee or a PhD programme committee is also considered. Neither external funding nor an employment contract with the university are seen as indispensa-

ble requirements for becoming a doctoral student in Finland. Therefore, there are doctoral students with varying positions in terms of attending research group activities and PhD programmes. Most doctoral students work on their studies part-time. A doctoral student has usually two supervisors: a main supervisor (a professor or principal investigator of a faculty) and another supervisor. The main supervisor is responsible for devising a personal study plan for each doctoral student, helping with administrative issues and supervising the research process.

Doctoral studies take approximately four years of full-time study to complete. They consist of formal studies that take an academic year (60 ECTS) and the PhD research project that aims to demonstrate independent and critical thinking. The formal studies include courses on research methodology, philosophy, academic writing and studies in the discipline. In addition, students are required to present their PhD research project in a research seminar at their own university and in international conferences. The project should be published as a PhD thesis at the end of their doctoral education.

The final version of a doctoral dissertation goes through a public examination. Before the final stage, the faculty nominates two pre-examiners to evaluate the doctoral dissertation manuscript. The pre-examiners write a recommendation to the faculty, based on which the faculty will decide whether the PhD thesis can be published and defended. For the public examination, the faculty nominates a chairman (*custos*), who is typically the main supervisor, and an opponent—in some cases, two opponents. The public examination begins with an introductory lecture (*lectio praecursoria*) by the doctoral candidate that lasts at most 20 minutes. The lecture introduces the main theme and research methods used in the PhD research project. Thereafter, the opponent gives a short statement about the scientific status and significance of the research and possibly highlights some other general issues. The examination continues with a discussion of the dissertation based on detailed comments and remarks by the opponent. The candidate is required to respond to the questions and comments made by the opponent and defend all the decisions and conclusions related to the research project in the best possible way. The opponent finishes the public examination by making a final statement and proposition of whether the faculty should accept the dissertation or not. The faculty accepts the thesis on the grounds of the opponent's recommendation. The department of teacher education uses a 7-point grading scale. The grade is recommended by the grading committee, which consists of the opponent and a nominated faculty representative.

FINNISH GRADUATE SCHOOL OF MATHEMATICS, PHYSICS AND CHEMISTRY EDUCATION (1995–2012)

The first network-type graduate schools in Finland were established in 1995. The graduate schools were financed by the Ministry of Education. The money was allocated for salaries, conference travelling and academic activities such as common doctoral courses. The graduate school system was established to shorten the time used for studies and to increase cooperation at both national and international levels (Önnerfors, 2007). Only some students received full-time payment, but many part-time students had scholarships or some other funding sources. The graduate school could cover some expenses for organising doctoral training, which made it possible for several doctoral students to participate. There were 119 graduate schools with 1,500 postgraduate positions in the whole Finland in 2007 (Ministry of Education, 2006).

The Finnish Graduate School of Mathematics, Physics and Chemistry Education (1995–2012) was also established in 1995. The school was established by five universities and their 18 departments. The partner departments included subject departments such as physics and mathematics departments as well as teacher education departments. Therefore, students were able to obtain their degrees either in the science and mathematics faculties or in the faculty of education. Typically, one of the supervisors was specialised in mathematics, physics or chemistry, and the other in educational sciences. Consequently, the school was interdisciplinary. At the beginning, the main goal was to focus on the develop-

ment of mathematics, physics and chemistry teaching in schools and building up the competence of science and mathematics teachers. In 1995, there were four full-time students, with the number increasing to 10 by the beginning of 1998. By that time, there were seven member universities with a total of 23 university departments involved with the graduate school. The number of part-time students varied from 55 to 75 (Lavonen & Strömdahl, 2008).

The Finnish Graduate School of Mathematics, Physics and Chemistry Education aimed to bring together Finnish researches of mathematics, physics and chemistry education to form a pool of supervisors for training experts in various fields of the graduate school as well as providing a broad scientific education. The educational environment was composed of research groups with international profiles and research contacts. The national graduate school organised one-week courses and seminars for all doctoral students. These common activities focused on topics such as scientific writing, research methodology and the philosophical basis of educational research. There were also some subject-specific lectures and individual supervision depending on the needs of doctoral students.

Supervision was provided both on a local basis and within the network of supervisors working in the partner institutes. Since the inception of the graduate school system, nearly 100 doctoral dissertations in mathematics, physics and chemistry education research have been published, of which some 40 were completed by students who had had full-time student positions of the graduate school at least partly during the studies.

THE NATIONAL-LEVEL GRADUATE SCHOOL AND INTERNATIONAL COLLABORATION

International collaboration for organising courses and supervision was an essential part of PhD education in the Finnish Graduate School of Mathematics, Physics and Chemistry Education. For example, several research methodology courses were organised within the Nordic Research Network in Science Education (NorSEd), with which the Finnish graduate school was involved. NorSEd was established with the financial support of NordForsk (Nordic Research)¹ and it aimed to strengthen the research network in science education and cooperation among the Nordic countries. This was seen as important for improving the quality of doctoral education in these countries.

Another essential format of the international collaboration were the joint researcher seminars organised together with Finnish, Dutch, Swedish and German graduate schools in 2007–2012. Realisation of collaborative doctoral education took place mainly through the joint seminars that were organised twice a year in summer and winter. The aims of the joint researcher training were intertwined with improving the quality and providing a broad overview of science and mathematics education to doctoral students who are building their expertise in their fields. The active role of all partners was at the core of orchestrating the activities (cf. Pyhältö et al., 2009). Since good-quality research is always part of and motivated by ongoing research in a particular research field, the first aim of the researcher training was to give doctoral students an insight into different research paradigms and traditions. This was considered important, as the basis of successfully conducted research is on knowing about commonly used theories and methods of education and instruction research as well as implementation and intervention research both at national and international level. Furthermore, the joint researcher training aimed at promoting interdisciplinary cooperation and crossing the boundaries of research traditions. As Cumming (2010) stated, understanding different approaches in the field can be seen as a basic competence of a researcher. International activities allow students to become members of an international research community and learn how to communicate about their work in English in both oral and written forms in a friendly and constructive environment.

International collaboration among graduate schools provides opportunities that ordinary conference

¹ NordForsk is an organisation under the Nordic Council of Ministers that provides funding for Nordic research cooperation as well as advice and input on Nordic research policy.

activities do not cover. In addition to presenting one's work in oral or written form, providing feedback on and reviewing other students' work are important tasks. Doctoral students are required to learn how to look at research critically and how to detect methodological or content-related shortcomings. This is valuable not only for evaluating students' work or published research, but also for developing prospective research ideas and projects. Furthermore, as the students' projects are typically interdisciplinary and focus on topics that need both pedagogical and deep subject knowledge, international collaboration provides an excellent opportunity to benefit from varying expertise and different approaches in the field of science and mathematics education (cf. Gatfield, 2005).

ESTABLISHING UNIVERSITY-LEVEL PhD PROGRAMMES IN 2014

In 2012, the Finnish Ministry of Education decided to close the network-type graduate school system and allocate resources directly to the universities and their faculties. For instance, the University of Helsinki decided to establish four schools for PhD education that aim to improve the quality of education and enhance the university's international visibility. A total of 32 PhD programmes started to operate under these four PhD schools at the beginning of 2014. The research fields of the four schools do not follow faculty or campus structures, but the doctoral programmes are closely related to the scientific fields. All previous 4,800 PhD students at the University of Helsinki were transferred to the new PhD programmes, and 200 new PhD student positions were filled. The organisation of PhD education and supervision in practice is on the responsibility of the PhD programmes. Approximately half of the PhD students have a full-time position as a doctoral student, and some of them have a position in a research project.

The recent movement has caused changes in organising doctoral education in science and mathematics education research. The Finnish Graduate School of Mathematics, Physics and Chemistry Education was no longer granted funding after 2012. Researchers in mathematics and science education representing the departments of teacher education, mathematics, physics, chemistry and biology started to plan a new type of programme for PhD education. However, an independent programme was not accepted by the University of Helsinki. Instead, a doctoral programme in in mathematics and science education research was accepted as a sub-programme of the Doctoral Programme of School, Education, Society and Culture (SEDUCE)². The aim of the multidisciplinary SEDUCE is to provide doctoral students with an in-depth knowledge of science education research and the capability to produce novel scientific knowledge independently. The programme brings together the research of various fields, forming a multifold pool of supervisors, but this time, within the university.

The new organisation of doctoral education is strongly located in the research groups of the university departments. Therefore, PhD education is conceived as an integral part of the research activities carried out in the groups. Consequently, supervision and guidance is based on daily interaction in university work that aims to help doctoral students integrate into the scholarly community and develop their professional identity (Pyhältö et al., 2009). This mode of PhD education is considered suitable for small research groups sharing interests and close collaboration. The doctoral students are thus already integrated into the research collaboration, networks and research community from the beginning of their academic careers. However, the practice varies among the various research groups.

Doctoral students are encouraged to communicate their research in international fora. The doctoral student is expected to participate and give a presentation in one to three national and international conferences annually, to submit papers to international refereed journals (usually with a success rate of one out of two submissions accepted) and to publish at least two papers in refereed conference proceedings. This helps maintain the high quality of scientific communication and allows students to obtain professional feedback on methods and research results. In addition, it helps doctoral students become acquainted with professional means of communication during their PhD studies. This mode

2 <http://www.helsinki.fi/behav/seduce/index.htm>

of combining research and PhD education more or less follows the same pattern as PhD education at the departments of physics, chemistry and biology, but is somewhat typical in the field of educational sciences. These “heavy” science traditions have also been followed in many research groups at the department of teacher education, especially in the research groups of science and mathematics education as well as educational psychology.

When reforming the university-level PhD education in science and mathematics education research, a special emphasis was placed on the quality of studies and supervision of the PhD students. Five approaches were recognised to uphold the quality of supervision, research and collaboration among the partners participating in PhD education:

1. *Recruitment and selection of PhD students.* General rules of the University of Helsinki are followed in the selection of candidates for PhD education. The selection is based on the research plan, publication plan and study plan. Moreover, the research plan should be related to the focus areas of the research community. These focus areas of research were recognised through an iterative process. In this process, the needs of society and the strengths of the research were taken into account.
2. *Strengthening supervision of PhD students* (cf. Gatfield, 2005; Lee, 2008). Each PhD candidate has a main supervisor, who is typically a professor taking responsibility for the student’s education, and one to two other supervisors. The educational environment contains sub-research groups in each participating department with international profiles and researcher contacts. The supervisors publish in conjunction with PhD students in international journals and books. As the research projects are interdisciplinary and focus on themes where both pedagogical and deep subject knowledge are needed, the organisational boundaries between the departments must be crossed in some cases. For example, there are seminars and national meetings where PhD students and supervisors from different departments interact with each other.
3. *Good practices, research group collaboration, courses and quality assurance in PhD education* (cf. Cumming, 2010; Humphrey et al., 2012). The senior PhD student researchers participate in the national and international seminars or other activities two to three times a year. For example, topics of the courses might be typically scientific writing and the philosophical basis of educational research. Evaluations and feedback of the PhD students are collected, analysed and discussed to develop the courses.
4. *Collaboration with other national and international PhD programmes.* An important part of the PhD education is organised through research projects and joint activities such as courses in research methodology and scientific writing. Up until now, the national network graduate school has managed to provide fruitful international collaboration for PhD students. PhD students and senior researchers have actively participated in international conferences such as EARLI, CERME, PME, ICME, NARST, AERA, GIREP and ESERA. Long-term collaboration has been organised with the graduate schools at the University of Duisburg Essen, Germany and the Swedish National Graduate School in Science and Technology Education Research (FontD), as well as Tallinn, Tartu and Oslo universities, among others. Some PhD courses have also been organised in Nordic cooperation. Both national and international collaboration encourage PhD students to become members of the disciplinary community and develop quality relationships. This type of enculturation is emphasised also in research literature (Pyhältö et al., 2009). Moreover, small nations and small areas of research benefit from internationalisation and collaboration between the different PhD programmes.
5. *Assuring good career prospects for the new doctorates* (cf. Baschung, 2010). PhD education aims to support PhD students in acquiring a wide range of research knowledge and skills in addition to concentrating on a specific research area. PhD students are expected to become autonomous researchers with special expertise in the future.

THE FUTURE CHALLENGES OF PhD EDUCATION IN SCIENCE AND MATHEMATICS

EDUCATION

The recent changes, establishment of university-level PhD programmes, have caused some issues that may influence the future of specific research fields. Well-organised and centralised doctoral education that is successful in recruiting the best PhD candidates guarantees that there will be well-educated and skilful researchers in Finland in the future (cf. Humphrey et al., 2012). It is assumed that individual universities have better opportunities to establish multi-professional research groups and integrate doctoral education as part of ongoing research activities than the former network type of graduate schools. According to Pyhälä et al. (2009), fostering PhD students' experience of active agency within the scholarly community is essential. There is still an urgent need to address the issue. Even if the development has been positive in some respects, we want to highlight the problems and challenges particular in the the field of science and mathematics education caused by giving up the national-level graduate school network.

First, the collaboration within the research field of science and mathematics education at the national level is hardly any more encouraged. Because doctoral education is organised within the universities, the network is mainly established between the departments of a university. The renewal of coordination and funding opens up new opportunities such as the possibility to learn from collaboration with other research traditions and disciplines. However, the number of researchers and doctoral students in science and mathematics education is low, and national collaboration within the field is needed. As Lee (2008) claimed, it is important to support enculturation, which refers to the scholarly community in general but especially in each discipline. The organisational and financial support for collaboration among universities is weaker than it used to be. In addition, as the recruitment system puts all doctoral candidates of different disciplines on the same line in contending for positions, there is no guarantee of having student positions for each discipline even occasionally. Therefore, the research community of science and mathematics education needs to think about other ways to encourage candidates to apply for other sources of funding, support part-time doctoral education and especially support their candidates in the application phase.

Another concern is related to international collaboration that has been a natural part of doctoral education in the network of graduate schools. The former national-level graduate school that was dedicated to research in science and mathematics education could apply for funding to organise international activities. International collaboration used to be a natural part of PhD education, which follows the idea discussed by Baschung (2010). However, the recent situation does not create a setting, in which several researchers of science and mathematics education representing different Finnish universities could apply for and organise collaboration with international partners.

How to guarantee both the quality and quantity of PhD education in the field of science and mathematics education is a serious concern. It is possible to develop the quality of supervision and support given to doctoral students at the local level. We need to take versatile approaches into consideration in supervision, as Lee (2008) suggests. We must also identify who benefits from the renewal of doctoral education and what we can do to take care of the continuum of high-quality PhD education that addresses the needs of our field.

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