

Promoting Young Science Education Researchers through a Series of International Seminars

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ABSTRACT

The aim of this study is to learn how a series of 3-day international seminars, emphasizing networking, and an academic writing, reviewing, and leading discussions, supports PhD students' professional learning and development by providing both a formal and non-formal context. The sample of this study consisted of PhD students from three countries – Estonia, Finland and Israel, and study was carried out in 2022 (in-person seminar; n = 20) and 2023 (hybrid seminar; n = 17). After the carefully designed 3-day seminars (including plenary lectures, workshops, and non-formal reflection sessions for PhD students), the feedback was asked from all participants in a format of questionnaire. In addition, interviews with two PhD students from each country were carried out to validate the outcomes from the questionnaire. Based on the results, non-formal activities were seen as supportive for getting to know their fellow PhD students and experienced academics in the field of science education. For many students, presenting their work or undertaking a review for another PhD student was a first-time experience and therefore gave them the opportunity to experience a wide range of activities supportive of being a researcher. In future studies, supporting PhD students long-lasting motivation to work on a doctoral thesis and to commit to PhD studies, can be used as one of the design principles in these types of seminars.

KEY WORDS: International seminar series; PhD education; science education

INTRODUCTION

Higher education, especially PhD or doctoral education, is considered as crucial for promoting research and innovation within the education sector in a country (Keeling, 2006; Guarimata-Salinas et al., 2024). In the context of science education, PhD holders are needed in science teacher education and in the development of science education innovations, such as learning foci and approaches, as well as assessment strategies. The number of PhDs in science education research, especially in small countries, is not high, while the studies and the courses provided are like those in countries worldwide having a bigger number of PhD students per programs. Unfortunately, at the same time, the number of PhD students completing their theses on time, is also small. Therefore, there is a need to consider, how to provide to PhD students supportive community for a progress in their studies and sharing their experiences, learning from each other and to establish international networks at an early stage of their career and, moreover, to increase students' motivation to finish their theses on time (Nerad and Evans, 2014). To provide PhD students with opportunities, despite the size of the country and number of PhD students, to exchange experiences, learn from each other, and be part of the academic community in science education, an option is international cooperation with other

countries, offering joint seminars, lectures, and workshops for the doctoral candidates.

To support PhD students (e.g., providing a professional network, meaningful workshops and interactive lectures), one trend has been toward structured and clearly organized PhD education seminars, aiming to support both formal and non-formal learning processes (Cumming, 2010). Research has shown that by providing PhD students with carefully and systematically developed seminars, including, for example, formal courses and non-formal gatherings, workshops, and academic writing while being forced to play different roles (session head, opponent to other PhD student etc.), supports their identity by becoming a part of the science education community (Addae and Kwapong, 2023; Caskey et al., 2022; Lavonen and Krzywacki, 2014). This understanding together with the literature review presented below has been important starting points for developing a series of international seminars for PhD students in the current study. Also associated with this, a further aspect has been the need to provide an experience of belonging to a broader science education community for PhD students in a small country.

Although, international research collaboration is considered as one of the most important aspects of academic career development (Bond et al., 2021), such collaboration has not

been a research focus in the context of PhD students for science education research. The topic is especially important in meeting the challenges faced in undertaking science education research in a small country with limited resources and small numbers of PhD students and researchers who can act as supervisors. The aim of this study is to learn how a series of 3-day international seminars, emphasizing networking and an academic writing, reviewing, and leading discussions, supports PhD students' professional learning and development by providing both a formal and non-formal context. In these seminars, science education PhD students from Estonia, Finland, and Israel participated as part of a project "Addressing Attractiveness of Science Career Awareness." This study is intended to contribute to enhancing PhD student education through learning from each other, developing a network for a future generation of science education researchers and sharing their best practices in undertaking research.

The following research questions are posed:

1. How do PhD students perceive the quality of provided activities and the interaction situations (both formal and non-formal) during the seminar series?
2. Which activities were perceived by PhD as supporting learning, based on individual perceptions?

The Literature Background

Studying for a PhD in education involves gaining a set of skills that support young researchers to feel safe, able to socialize, and gain a sense of belonging in their own research community (Gardner and Mendoza, 2010). For example, encouraging enculturation, ensuring PhD students become members of the disciplinary community, and developing an interactive, high-quality relationships, seen as both inspiring and supporting students during their studies, are considered essential to facilitate students achieving a PhD degree (Pyhältö et al., 2009). Below, four main characteristics are elaborated supportive for effective PhD education studies, which provide students a supportive community for sharing their experiences and learning from each other through international collaboration and seen as increasing students' motivation to complete their thesis on time (Nerad and Evans, 2014).

Formal and Formal Curricula and Learning

Elliot et al. (2016) summarizes the characteristics of a PhD education curriculum as a formal curriculum introducing aims and a planned schedule of experiences and activities that students are required to undertake as part of their PhD degree program. This formal, or structured PhD education orientation, is strong adopted in the three countries involved in the current research. On the other hand, a non-formal curriculum emphasizes activities and options for non-formal meetings and discussions that are not assessed and are not part of the formal curriculum, although they often support learning and provide possibilities for reflection (Elliot et al. 2016). Such activities are driven by personal questions and are self-directed (or a proactive pursuit), incidental (or an unintentional endeavor), and include tacit learning, leading to internalization of values, attitudes, behaviors,

and skills through socialization with others (ibid). Elliot et al. (2016), in analyzing this enculturation, within the context of Bronfenbrenner's (2005) bio-ecological system framework, sees a full appreciation of human development as warranting recognition of the different contexts influencing a person's overall development. Such enculturation is seen as encouraging PhD students to become members of the disciplinary research community and developing a quality relationship that both inspire and support their research and feeling of belongingness within the community (Pyhältö et al., 2009).

Internationalization

Myklebust and Withers (2017) argue that internationalization of PhD education is important for the development of research practices and as a support system (incl. disciplinary network) for PhD students in a small country with low numbers of PhD students in the field of education. International collaboration, such as the organizing of common international courses and seminars, is common in PhD studies and aims to support PhD students learning in formal and non-formal situations (ibid). International collaboration also supports supervisors to learn different supervisory and content-related practices and thus develop their local practices, revise supervision and adopt formal courses. A well-known example of an international seminar is the European Science Education Research Association (ESERA) doctoral school for PhD students, whereby young researchers attend plenary lectures, participate in workshops provided by experienced mentors and join mentor group seminars, as well as participate in social events prepared by an organizing committee (Rokos et al., 2017). According to Baschung (2010), Myklebust and Withers (2017) inviting international keynote speakers, organizing international peer-reviews commenting on the PhD students' proposals and offering possibilities for international presentations as well as non-formal discussions, also supports the internationalization of PhD studies in education.

Collaboration and Communication

Important characteristics of PhD education is PhD students' active role in collaboration and interaction activities during various formal and non-formal collaboration, interaction and supervision situations (Pyhältö et al., 2009; Corcelles-Seuba et al., 2023). One component is PhD seminars, which can provide more meaningful opportunities for collaboration and interaction than ordinary lectures in classrooms, or even conference activities, such as a PhD student's role as a reviewer of other students' manuscripts or acting as an opponent in a session. Discussions in a seminar offer possibilities for learners to reflect critically on their research and detect methodological or content-related shortcomings (Gatfield, 2005). Encouraging PhD students to undertake an active role in seminars aligns with Elliot's et al. (2016) recognition from their enculturation study that PhD students, themselves, need to be able to align with complex interactions at different levels, which play a crucial role in their PhD studies. Enculturation, or development of a 'collective identity' and acquiring an expert knowledge base happen both through formal presentations, such as keynote addresses and non-formally, such as in coffee break

discussions (McAlpine and Amundsen, 2009; McAlpine and Norton, 2006).

Learning from other people through collaboration and interaction is not straightforward. Eraut's (2007) conception of learning from other people, referred to as cultural knowledge, is acquired through participation in social activities. Such cultural knowledge has a strong tacit and practical component permeating beliefs and behavior. However, people are often unaware how non-formal knowledge can inform "personal knowledge" (Eraut, 2007).

Professional Development Activities

Lee and Kamler (2008) have analyzed the role of writing research articles as a part of PhD studies, based on two case studies that illustrate ways of supporting PhD students in writing. They argue that writing a small number of articles, or other publications indicates a low quality of PhD education and does not prepare PhD students to participate in a research culture. Furthermore, they argue that issues of writing and engaging in publications need to be systematically addressed within PhD education and supported by appropriate guidelines and seeking possibilities to present the outcomes to a wider audience. Humphrey et al. (2012) emphasize that writing and publishing needs to be systematically addressed within PhD education. Writing prepares PhD students to participate in the research community and adopt a culture of research (Ribau, 2018; Stevenson, 2021). Training in academic writing is seen as having a positive influence on studies at PhD level in several countries (Humphrey et al., 2012; Lavonen and Krzywacki, 2014, Ribau, 2018).

PhD Studies in Science Education in Finland, Estonia, and Israel

The three countries were selected because they were willing to participate voluntarily in the project. All three are active in science education research and educating PhDs in science education. However, the populations are rather small, and resources limited. Based on the World population review¹ an average number of PhDs graduating yearly in educational sciences per one million inhabitants are 25 in Estonia, 24 in Finland, and six in Israel. Corresponding numbers for big countries are: four in the US, 14 in UK, and five in Germany. The exact number of yearly graduating PhDs in science education research is not available but could be estimated to be about 10% of all PhDs in education. Consequently, the three countries are interesting, because they are small by absolute numbers of science education PhDs and resources, but they are very active in encouraging PhDs in science education.

Finland

Since 1960s, the general aim of PhD studies has been to develop students' in-depth knowledge of research and their capability to produce novel scientific knowledge. However, 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

1. <https://worldpopulationreview.com/country-rankings/doctorates-awarded-by-country>

directly to individual universities for organizing their own PhD programs, instead of subject specific national-level graduate schools, which were common in the mid-1990s (Lavonen and Strömdahl, 2008; Önnersfors, 2007). The recent aim has been towards structured and clearly organised PhD education that aims to support the learning process of PhD students (Cumming, 2010). However, this aim does not support studies in subjects with small student numbers, like science education in a similar way to that with the previous model. This is one of the reasons, why the science education research community has been willing to collaborate internationally to ensure wider PhD students and supervisor exposure. However, the faculties in universities have always been and remain the main actors in PhD education and in offering the degrees.

A PhD in science education can be completed either in the Faculty of Science, or in the Faculty of Education. Research, typically, is carried out within a research project, financed through

external funding. PhD studies take approximately 4 years of full-time study to complete. They consist of 40 ECTS of formal studies plus the PhD research project, which 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 also in international conferences. The research project is published as a PhD thesis although the thesis can be a monograph or a collection of three journal articles plus a summary. The articles are typically written in a team as part of a bigger research project. However, the PhD student needs to be the first author in all articles. In science education, an article-based thesis is the most common. The final PhD dissertation is subjected to a public examination.

Estonia

PhD education in Estonian universities has gone through several changes in the past decades. A master's qualification is required for entry to PhD studies. From the 2022/2023 academic year, PhD student places are mainly offered as state-funded junior research fellow positions. Each year, junior researchers (and former PhD students) undergo annual attestation to recognize their progress in research. During the attestation seminar, a committee listens to the presentation from each student and offers advice to students on their research progress. The junior research fellow's salary is comparable to the Estonian average salary. Before year 2023, PhD students received monthly scholarship at a financially lower level. Despite the organizational reforms, the main component of the PhD studies has always been research. The research dissertation can be either a published monograph or be article based.

In the University of Tartu, science education is part of the PhD program in Educational Sciences. The program consists of 30 ECTS formal studies (e.g., academic writing, leadership,

qualitative and quantitative research methodology, educational theories, science methodology, trends in (science) educational research), and 210 research ECTS. In this curriculum, the dissertation is based on three published articles in peer-reviewed journals plus a summary. It is expected that the PhD student, or junior researcher, is the first author in published articles. The final PhD dissertation goes through a public examination.

In addition, PhD students (junior researchers since 2023) are required to present their studies in national and international seminars, conferences, and workshops. The purpose of this is to generate new research-related contacts and to build a personal network. It is also expected that each PhD student, or junior researcher, develops leadership skills through supervising several Master thesis's during their own studies.

Israel

The Department of Science Teaching at the Weizmann Institute of Science offer MSc and PhD graduate programs in science and mathematics teaching. There are, on the average, about 30 students each year (new and continuing), most of them PhD students in this program. The admission requirements include a strong disciplinary background and preferably experience in mathematics or science education, although this can be obtained during the graduate studies. The program is adapted to the background of the students and offers disciplinary courses, mathematics and science education courses, and general courses in education and educational research such as: research methods, curriculum development, and cognition. Every graduate student is guided by a faculty advisor in choosing the courses, as well as in his/her research thesis topic.

Graduate students play a central role in the department's research and development activities. They have opportunities to experience a rich array of areas in mathematics and science education that equip them for a variety of career choices after completing their graduate studies. Many of the academic positions in science and mathematics education in Israeli universities and colleges are held by graduates of this program. The other graduates hold a variety of leadership posts (from school headmasters to national science or math supervisors in the Ministry of Education). Many of the theses have had an influence on Israeli curricula and teacher development programs and, as a result, have had an impact on science education in Israel. They have also contributed to the international mathematics and science education community, in the form of presentations and invited lectures in conferences, as well as papers in highly regarded journals.

METHODOLOGY

This study is based on two 3-days international seminars (held in 2022 and 2023) systematically developed to support PhD students in science education.

Study Design

The design principles of the international PhD seminar series come from the four characteristics, emphasized in the literature review above:

1. Combining formal and non-formal activities
2. Possibility to collaborate and communicate
3. Possibility to discuss about science education research in an international environment
4. Preparing a paper and giving a presentation as part of professional development within the seminar and acting as an opponent for a fellow PhD student.

In both seminars, PhD students and supervisors were expected to actively participate and engage in multiple roles (including participating in workshops, lectures, presentation sessions, and reflection groups). For example, during the PhD students' presentation sessions, PhD students took an active role in being an opponent to a fellow student or guiding the general discussion during sessions. Supervisors were expected to chair sessions and undertake feedback for the presenters in their sessions. This was undertaken to ensure that both PhD students and their supervisors gained a rich experience from these seminars.

Even more, during the lunch time, discussions were encouraged with the presenters, opponents and sessions chairs to increase non-formal reflections of the sessions. And, in addition, to support PhD students' own reflections about their experiences from the plenary lectures, workshops, presentation sessions, at least two 30 min reflection slots for PhD students (in freely formed groups), were included in the seminar agenda. Table 1 gives an overview of activities and formats used in both PhD students' seminars.

After the seminars, the papers presented by students were expected to be developed further, based on the feedback with the goal of eventually submitting the paper to an international refereed journal thus indicating the quality of the author's scientific communication skills that have developed thanks at least in part, to the professional feedback guiding the quality of the research and the appropriateness of the results.

Participants

In 2022, 20 students from three countries participated in the 3-day international seminar and 16 of them completed a feedback questionnaire after the seminars. In 2023, the corresponding numbers were 17 and 15. Due to the small number of PhD science education students in the selected countries, no country comparisons were made, and all participants were taken as a single data set for analysis.

Data Collection Instruments

The process of designing, refining, and piloting a questionnaire, used for acquiring quantitative data, was iterative and undertaken by the authors of this study.

A prototype questionnaire was designed in line with the research outcomes on the effectiveness of PhD education, especially, related to:

- (a) What is currently known about the influence of formal and non-formal learning in PhD studies (Elliot et al., 2016)
- (b) Internationalization of PhD studies (Myklebust and Withers, 2017; Rokos et al., 2017; Baschung, 2010)

Table 1: An overview about the activities in PhD students' seminars

Seminar	Activity	Format	Explanation	
2022				
Day 1	2 Workshops	In-person	The sessions were in-person and participants from all 3 countries were involved (incl. all workshop and plenary lecture providers)	
Day 2	3 Plenary sessions PhD students' presentation sessions (10 parallel sessions, 45 min for each PhD student presentation) PhD student's poster sessions (1st year students)	In-person In-person		
Day 3	3 Plenary sessions PhD students' presentation sessions (4 parallel sessions, 45 min for each PhD student presentation)	In-person In-person		
2023				
Day 1	2 Plenary sessions PhD students' presentation sessions (2 parallel sessions, 45 min for each PhD student presentation)	Hybrid 1 hybrid, 1 in-person		This seminar was in a hybrid format – participants from Estonia and Finland were in-person and participants from Israel were online. Plenary lectures were also in a hybrid format – one lecturer was attending in-person, and one was online.
Day 2	PhD students' presentation sessions (6 parallel sessions, 45 min for each PhD student presentation) Plenary session Workshop	3 hybrid, 3 in-person Hybrid Hybrid		
Day 3	PhD students' presentation sessions (4 parallel sessions, 45 min for each PhD student presentation) Group Discussion and summing up – What have we gained from the autumn school?	2 hybrid, 2 in-person Hybrid		

- (c) Collaboration and communication in PhD studies (Pyhäntö et al., 2009; Corcelles-Seuba et al., 2023; McAlpine and Amundsen, 2009; McAlpine and Norton, 2006)
- (d) Professional activities, such as writing in PhD studies (Lee and Kamler, 2008; Ribau, 2018; Stevenson, 2021).

The prototype questionnaire was first tested in a small-size international seminar in October 2021. Based on the outcome, the wording of the questionnaire was improved and new questions, related to professional activities, especially items related to reviewing a proposal, were added. The second piloting was organized in an international seminar in December 2021. The refined questionnaire was utilized in the seminars in years 2022 and 2023.

Utilizing the questionnaire, the PhD students were asked at the end of the seminar to evaluate:

- (a) The perception of the quality of the provided activities during the seminar plus the interaction situations (both formal and non-formal)
- (b) The supportiveness of the activities for the development of academic competences.

Items were both Likert-scale closed questions and open questions as described in the result section. The validity of the items in the questionnaire was determined by expert validation – two supervisors from each project partner country were involved in the revising of the questionnaire during development and indicated its suitability for the project goals. They also validated the questionnaire against its relevance to the four seminar design principles, based on the literature.

After the initial analysis of questionnaire data, it became evident that there was a need to examine the participants'

intentions behind the questionnaire responses. For this, eight students were interviewed from the three countries. Participation in the interviews was voluntary and the only criteria utilized for the selection of participants was that all three countries should be represented to ensure the richness of the PhD experience. No additional interviews were considered due to the small sample size of the students in the current study. Interviews were conducted in the English language by one of the article authors via Zoom (approximately 45 min). Zoom was used to record the interviews and after transcription, recordings were deleted. The design principles on which the seminars were developed, and interview questions were as indicated in Table 2.

Each interview began with an introduction outlining the purpose of the interview, confidentiality agreements and a description of the overall interview process. Then, the five structured questions were asked to ensure that the responses from participants could later be seen as comparable, based on the questions. If necessary, clarifications were asked from the based on their responses to the structured questions.

Data Analysis

By combining quantitative and qualitative approaches to enhance the credibility and validity of the research findings, PhD students' perceptions about international seminar series were analysed. Also, this approach helped to place quantitative findings within a broader qualitative context seeking to make quantitative findings more meaningful and applicable to PhD education settings in putting forward recommendations.

Data from the questionnaire were analyzed using descriptive statistics (mean, standard deviation) and items ranked

Table 2: The interview questions

Design principles of the international seminar	Interview question
1. Combining formal (perceived value of lectures, seminars, workshops) and non-formal (gatherings) activities	When you think back on the last PhD students' school, what would be the most significant aspect/activity/event you would like to highlight? Why was this important to you?
2. Internationalisation (developing a personally relevant network)	Do you keep in contact with other PhD students, met in the PhD school? And if so, do you now feel more part of a science education community than before this event?
3. Collaboration and communication	
4. Professional development activities (writing draft paper for a wider audience prior to the PhD school, acting as a reviewer in the PhD school, providing critical feedback, implementing gained knowledge and wisdom after seminar in one's own work)	Going beyond the previously mentioned aspect/activity/event, are you now implementing/using the gained know-how in undertaking your studies and research? Did you notice any increase in motivation in undertaking your doctoral thesis studies after the PhD school?
5. Suggestions for improvement	Do you have any suggestions for future PhD schools events to better meet your expectations?

according to means. Data from the interviews were analyzed using qualitative content analysis (Cohen et al., 2018). The coding of responses was conducted in English, and to ensure the validity of the developed codes and categories, expert validation was employed, until a consensus was reached for the codes and categories across all responses. Three experts were involved, represented the project partner countries. The outcomes from the interviews were used to validate the results from the questionnaire, given the small sample size in the current study.

RESULTS

PhD Students' Evaluations of the International Seminars

Table 3 indicated how PhD students experienced the seminar activities and pointed out that the quality of these activities was, in general, high. Activity quality seen as associated with the characteristics of the activity, such as its structure, engagement, and supportive for achieving its intended objectives.

Students were also asked to write comments related to the quality of the activities. The comments were generally short and positive, such as, "*there was enough time for non-formal discussions and also discussion time after the presentations*" and "*the program format worked.*"

Although the differences in outcomes between the 2 years were relatively small, Table 3 indicated that interactions with students from other countries were evaluated at a lower level in 2023, compared with 2022. This might be influenced by the fact that all students from one country were online and students from the other two countries were present in-person.

Table 3: Students ($n_{2022}=16$; $n_{2023}=15$) evaluations of the quality of the activities (scale 1=Poor and 5=Excellent)

Items	PhD students 2022		PhD students 2023	
	Mean	SD	Mean	SD
1. Quality of plenary lectures	4.53	0.64	3.92	0.86
2. Quality of workshops	4.71	0.47	4.17	0.72
3. Quality of PhD students' presentations	4.59	0.62	4.73	0.46
4. Quality of sessions chairs feedback	4.43	0.65	4.73	0.59
5. Quality of opponents' feedback	4.31	0.70	4.60	0.63
6. Quality of discussion after the students' presentations	4.31	0.70	4.73	0.46
7. Quality of the interaction situations	4.61	0.70	4.20	0.86
- Between the supervisors/professors and PhD students	4.27	0.80	4.47	0.74
- Between PhD students from his/her own country	4.35	0.70	4.67	0.72
- Between PhD students from other country	4.61	0.78	4.13	0.99

In particular, Table 3 pointed out that:

(1) The quality and level of interactions between supervisors/professors and PhD students increased from 1 year to the next. This could be interpreted that students were more familiar with the persons attending the seminar and had more courage to interact in discussion, to initiate the discussions and already knew each other's expertise in seeking advice. Furthermore, students preferred to communicate more with students from their own country (2022: $M=4.35$; $SD=0.70$; 2023: $M=4.67$; $SD=0.72$).

(2) In the first seminar (2022), all activities were in-person, while in the second one, they were in hybrid format (2023). This might explain the difference in students' feedback on the lectures and workshops as indicated in Table 3. In both years, students evaluated workshops and lectures more highly when they were in-person and not in hybrid format.

(3) As the intended role of seminars was to support PhD students' professional development in academic research and community, the PhD students, based on the outcomes from the questionnaire, indicated a higher quality in PhD students' presentation sessions, session chairs, and opponent's feedback (Table 3) in 2023, compared with 2022.

When asked to rate activities regarding their professional learning as a PhD student, student evaluations were very positive, as presented in the Table 4. The table indicated that the plenary lectures were not considered as supportive of learning in year 2023 as they were in the year 2022. These changes could be explained with the change of format of sessions – in 2023, plenary lectures were in hybrid format, but the structure and length were similar to the in-person lectures in 2022.

Key findings from the evaluations of the PhD seminars were:

(1) While a key aspect in this study was to purposefully include non-formal activities during the PhD school,

Table 4: Students (n₂₀₂₂=16; n₂₀₂₃=15) evaluations of the PhD seminar for professional learning (scale 1=Do not support my learning at all and 5=Support my learning a lot)

Items	PhD students 2022		PhD students 2023	
	Mean	SD	Mean	SD
Writing of a proposal and a review	4.44	0.89	4.20	0.94
Preparation of the proposal				
Preparation of the review	4.31	0.79	4.07	0.88
Interaction and collaboration	4.60	0.74	4.73	0.80
Giving the presentation				
Working as an opponent	4.27	0.70	4.40	0.63
Opponent feedback	4.14	0.66	4.27	0.88
Session chairs feedback	4.29	0.73	4.40	0.91
Audience feedback after the students' presentations	4.53	0.52	4.20	0.86
Following the other students' presentations	4.41	0.71	4.27	0.88
Formal activities	4.27	0.80	3.36	1.15
Following the plenary lectures				
Participating workshop	4.57	0.65	3.92	1.08
Poster session	4.13	0.96	4.33	1.15
Non-formal activities	4.61	0.61	4.40	0.83
Non-formal discussions during the seminar with other students				
Non-formal discussions during the seminar with supervisors/professors	4.38	0.81	4.60	0.63
Non-formal discussions during the evening	4.64	0.63	4.08	1.19

outcomes from Table 4 indicate that non-formal discussions with fellow students were more highly evaluated associated with the in-person format, compared with the hybrid format. These discussions were found to be hard for students, because of the mixing of hybrid and in-person involvement.

- (2) From a professional learning sense, findings indicate (as in Table 3) that in-person workshops worked better for students compared with those which were in a hybrid format.

Students were also asked to write comments related to the seminar in the questionnaire. The comments covering the four design principal areas for the seminar were as indicated below:

- Combining formal (lectures, presentations, and workshops) and non-formal, (discussions during the breaks and dinners, social events):
 - It was nice to learn about other cultures during the non-formal meetings
 - The non-formal interactions and networking were very important
 - I felt that the seminar supported my studies and was a safe learning environment, but the schedule was somewhat exhausting and could have been more varied, also physically. I struggled to keep my focus

by the end of longer sessions during the long days

- More social interactions/programs for PhD students. More free time for spa, saunas, outdoor activities, etc. It was a very busy official program. More workshops for PhD students, who just started, or who plan to finalize soon

- Thinking and communicating with others helped to organize my research-related thoughts.
- Internationalization (developing personally relevant network)
 - Experience in giving international presentation
 - Talking, presenting, and hearing about different kind of research is great and improves/helps a lot
 - Non-formal reflections/discussions with students from other countries are very valuable. They help me to position my own research and provide insights for future work
 - This seminar was very useful for me as a PhD student, because I got the opportunity to socialize and discuss my work with other, more experienced PhD students. The feedback they gave me was invaluable for me to progress with my work
 - It is good to “come out” from my own studies, and to see, what the others are doing. During PhD sessions, I got new ideas, and I also learned from the others, how they made their presentations.
 - Collaboration and communication
 - Good opportunities for networking and discussions
 - Seminar enabled meaningful interaction
 - Help to network and learn from other PhD colleagues
 - It is what it is, you present your topic and during that you probably improve.
 - Professional development activities
 - The event was very well organized. It was good, that every PhD student had to make a presentation and write a review. All this preparing process and presentation was a good way to achieve and practice necessary skills. PhD students, supervisors, and organizations were very friendly, and helpful; it was easy to communicate
 - I received helpful feedback, that is, literature and links to the articles both from the students and participating professors.

These comments indicated that, in general, PhD students found the format of the seminars useful for their professional learning and networking (internationalization and communication). Based on their feedback, the need for co-writing sessions, round-table discussions, and bigger time for reflections, could be considered in future seminars for PhD students.

PhD Students' Interviews

Four main categories emerged from the interviews: collaboration and communication, professional development, motivation to do PhD thesis, and internationalization (Table 5). Motivation as a separate category emerged from the interviews, although this was not part of the initial design principle in the current

Table 5: Summary of the interview data analysis (number refers to frequency in responses)

Main categories	Sub-categories	Code	Example of PhD students' answers
Collaboration and communication (14)	Social interaction (9)	New contacts (6); Communication with PhD students (3)	<i>"Summer school really supports making contacts"; "I got connected with people outside of my university"</i>
	Community support (5)	PhD student's community (2); Educational scientist community (3)	<i>"I recognised myself as part of a community in science education"; "I feel belongingness to the science education research community, and this builds self-confidence"; I can see what other people are doing in science education research"</i> <i>"Non-formal activities in a community reduce anxiety when giving a presentation"</i>
Professional development (33)	Usefulness (15)	Giving feedback (5); Getting feedback (5); Focusing on research (3); Awareness of research in science education (2)	<i>"I got useful comments for my upcoming paper"; "This was my first time to act as a reviewer and I learned a lot, e.g., how express my feedback"; "This was first time I prepared a review" "Feedback from PhD students is closer to my own level compared with feedback from professors"</i>
	Competence for research (11)	Presentation skills (5); Theoretical background (2); Research methods (4)	<i>"The workshop on validity was good for me"</i>
	Learning from others (7)	Learning from other PhD students (5); Learning from experienced researchers (2)	<i>"I analysed my own work in the light of experiences by others and noted we had similar difficulties"; "I learned from presentations by that presenting research outcomes is like telling a story; not summarising academic achievement"; "It is not enough having a supervisor; you need other perspectives, advice and different viewpoints"; "I supported PhD students by sharing my own experience"</i>
Motivation to develop a PhD thesis (11)	Self-confidence (4)	Experience of success (3); Recognising the importance of my work in research (1)	<i>"The seminars made me feel confident in my abilities and to continue my academic career"; "I got more confidence; I saw people in the same situation"</i> <i>"We are talking the same language in a science education community, and it builds self-confidence" "Other people found my research meaningful"</i>
	Motivation (7)	Raising motivation (7)	<i>"After this kind of summer school, you experience a raise of motivation, even if it goes down after some time due to daily activities"</i>
Internationalisation (5)	Cultural differences in PhD studies in science education (4)	Conducting research in different cultures (4)	<i>"Learning how research problems are looked at in different cultures"; "During the seminar, participants are realising different viewpoints, how PhD students look at the research problems from different countries, this is a highlight in this kind of seminars"</i>
	Cultural differences in in education and teacher training systems (1)	Science education and teacher education in different contexts (1)	<i>"It was interesting to discuss with people from other countries how they are teaching science in school"</i>

study. However, it was noted that this is an important result, indicating that the content of seminars also supported students' motivation to work on their thesis and even though this motivation was considered short term (2–3 months following the seminars) and that, after this, motivation declined due to other responsibilities in their professional and personal lives). Based on this, one key suggestion could be the systematically development of seminars for PhD students seeking to support

and raise motivation during PhD studies. The findings in Table 5 also indicate that combining the formal and non-formal activities did not emerge as a separate category and responses focusing on these aspects were spread over other categories.

The Findings from the Interviews were Elaborated in Table 5.

PhD students answer to the fifth question were analyzed separately. The students recommend some minor changes to the activities (e.g., different activities for 1st year PhD students

and 4th year PhD students). Several students suggested that the presentation reviews and workshop materials could be available before the seminar enabling the getting to know the content and preparing questions. Students also recommended to have more time for workshops and PhD students' presentation sessions, distributing lectures and workshops more evenly over all days and including a joint writing session for PhD students to support the development of writing skills. These types of suggestions were as also among the answers to the open questionnaire questions.

DISCUSSION

The aim of this article was to investigate PhD students' perceptions and learning in the context of international PhD seminars, focusing on young researchers gaining research competence through collaboration between institutions in three countries (Finland, Estonia, and Israel). The four design principles behind the planning of the seminars i.e. combining formal and non-formal activities, seeking possibilities for collaboration, interaction and writing activities and internationalisation were seen as productive design principles for a PhD seminar.

The PhD students' answers to the questionnaire's closed and open questions and responses in interviews were taken to indicate that the international PhD seminar series was of good quality and supported students' learning, collaboration, and interaction during their PhD journey. The quality of their PhD education seems to be associated with the characteristics of the seminar activities, such as structure, engagement, and supportiveness for achieving the intended objectives.

Students considered both formal sessions, such as presentations and working as an opponent, and non-formal learning during the coffee breaks discussions, as supportive for their personal learning. In fact, most students considered that there should be more possibilities for non-formal interaction and the sharing of experiences within the PhD studies during the seminar days and evenings, in line with both Cumming (2010) and Elliot et al. (2016) views. Although, the program was aimed to include enough time for non-formal discussions through having long enough coffee, lunch, and dinner times, this was not so successful in encouraging the combining of formal with the more common, non-formal discussions. It seemed that students could benefit from the non-formal discussion sessions being more guided, perhaps organized by experienced PhD students. This enhanced guiding could help all students to not only engage in more focused non-formal discussions, but in promoting enculturation and the development of a "collective identity" and an expert knowledge base (Austin, 2010; McAlpine and Amundsen, 2009; McAlpine and Norton, 2006).

The international PhD seminar series were seen as offering a useful start for PhD students in their international career and enabling networking with scholars in the field as both Baschung (2010) and Myklebust and Withers (2017) recommended. Especially, students new to PhD studies,

considered the connections with more experienced students useful for their networking and they valued the international presentations (plus the comments by other PhD students' and other supervisors on their own work), as offering broader views than views gained in local seminars. According to Baschung (2010), these types of activities were supportive of the internationalization of local PhD education, facilitating progress in their PhD education.

The collaboration and interaction within the programme were highlighted as supportive of being part of a research community, providing a wider exposure and enabling the development of competences, such as in editing papers, or creating connections and networks. The involvement in new experiences, such as writing of a research proposal and undertaking a review, were considered as enhancing the development of their own competences as a researcher. Both requirements helped in the editing of a developed paper and becoming familiar with additional, relevant research papers. In fact, the participants indicated that the writing – feedback – review was recognized as very supportive of PhD students' learning and was in line with that recognized as influential for studies at the PhD level in various countries (Humphrey et al., 2012; Ribau, 2018). It also enabled participants to recognize that others had similar problems, and getting different perspectives from a wider group helped to raise confidence and reduce anxiety in moving forward.

However, according to the PhD students' evaluations, more time should be allocated to student centered formal activities, such as co-writing workshops and non-formal collaboration and discussions. Moreover, the students recommended analyzing the intensity, or the workload, per day and distribute formal and non-formal activities more evenly across all days. In this respect, they recommended that PhD students' evaluations and workshop handouts should be more rigorously planned and organized.

International collaboration was a key part of the international PhD seminar, following the idea introduced by Baschung (2010). Based on the student answers and interviews, internationalization of PhD education was viewed as important for students' formal and non-formal learning which, in a similar way, Hung (2018) emphasized based on Asian experiences (Baschung, 2010; Myklebust and Withers, 2017). Students, especially, recognized the learning value from undertaking a review of other students' papers from a different country. Participants in these seminars valued this even more than learning through self-writing a paper.

International collaboration was also seen as providing different experiences than in an ordinary conference. Participants commented that it was good to be aware of how research was viewed in other countries. This was especially through the providing of feedback on, and reviewing of, other students' work. The possibilities to receive feedback during the seminar, not only from one's own supervisor, but also from a supervisor from another country, were recognized as supportive of learning

(Gatfield, 2005; Lee, 2008). Finally, students emphasized the importance of learning about cultural differences in PhD studies and, more generally, in education and teacher education systems. Consequently, this international collaboration offered possibilities for learning skills and abilities, which could be transferred to new contexts (Åkerlind and McAlpine, 2017).

Although writing of paper drafts was recognized as important for learning during the PhD studies (Humphrey et al., 2012; Lee and Kamler, 2008), this was not considered as supportive for learning as was interaction, collaboration, internationalizing, and non-formal interactions by the students. The review of another student's paper was seen as one of the most useful formal activities in the seminar. Thus, participants agreed that writing-related activities were important for students learning and, as such, agreed with Humphrey et al. (2012) that writing needed to be systematically addressed within PhD education and supported by an appropriate pedagogy. In this international PhD seminar series, the guidelines for writing the paper and making a review were seen as positive indicators in supported students in paper writing and developing reviews. On the negative side, the participants felt that there was insufficient time allocated during the sessions for both presenting the paper and presenting the review.

Practical Implications for PhD Education

Practical implications for PhD education can be summarized as follows:

1. In-person seminars to support PhD students are seen more useful for students than compared with hybrid ones. Collaboration and internationalization are important characteristics of the seminars
2. PhD students' seminars need to be purposefully built to support students' motivation to work on their thesis. Even if this aspect is not deliberately planned, students need to feel the raising of motivation in this type of seminars
3. Students need to have enough time for writing a preliminary proposal according to guidelines. Then peer reviews of the proposals need to be organized, and PhD students need to be given a review guideline. In the seminar there needs to be enough time for presentations and feedback from opponents, other students, and supervisors. A clear seminar guideline and schedule guide are needed for the seminar activities
4. There needs to be a balance between formal and non-formal activities in seminars and time for students to reflect on their experience from the seminars. It is important reflect on ensuring sufficient time for non-formal activities and discussions.

CONCLUSION

This study posed two research questions. First research questions focused on how students perceived the quality of provided activities and the interaction situations (both formal and non-formal) during the seminar series. The international seminar series fulfilled the goal of supporting PhD students in science

education. PhD students experienced the international seminar series as useful and supportive their PhD studies and becoming a member of the science education research community. The quality of the activities, based on student's feedback, was indicated, in general, to be high. The close collaboration between two small EU member countries turned out to be a practical solution for organizing PhD students' seminars with sufficient students present, enhanced by having a foreign and neutral opponent per PhD student from other research groups. Based on the interviews, international collaboration supported this enculturation. It could be concluded that, based on the students' responses, it was possible to integrate formal aims and a planned schedule of experiences and activities, which students were required to undertake as either formal and non-formal activities, with choice driven by personal questions, and options provided for non-formal meetings and discussions, in the context of an international PhD seminar.

Second research question focused on which activities were perceived by PhD as supporting learning, based on individual perceptions. Based on the results, non-formal activities were seen as supportive for getting to know their fellow PhD students and experienced academics in the field of science education. For many students, presenting their work or undertaking a review for another PhD student was a first-time experience and therefore gave them the opportunity to experience a wide range of activities supportive of being a researcher.

Noting the findings from this study, we can recommend that developing an (international) seminar series for the PhD students are appropriate and reasonable events to raise students' competence in conducting research in science education and develop a feeling of belonging within a science education community. In future studies, supporting PhD students long-lasting motivation to work on a doctoral thesis and to commit to PhD studies, can be used as one of the design principles in these types of seminars.

Critical Reflection on Potential Biases and Alternative Interpretations

Because our sample size is small, we collect quantitative and qualitative data to understand, holistically, the phenomena - PhD education in international collaboration. This type of multiple data sources and research methods aims to validate the findings (Sammons and Davis, 2017). As researchers, we acknowledge our own potential biases and have strived for transparency in reporting the study and its biases and limitations.

Below, we summarize potential biases and alternative interpretations of the data in line with the guidelines offered by Cohen et al. (2018), Fowler (2014), and Powney and Watts (2018). We have sought to reduce response bias through,

- (a) Careful wording of the interview questions and using natural language to avoid leading the responses
- (b) Ensuring the interviewer was one of the senior researchers, participating in the project - not the PI or co-PIs of the

project – to avoid participants providing socially desirable answers and, on the other hand, avoid polite answers.

In the beginning of the interview, voluntary participation was emphasised, and the participants were assured that their responses would be anonymous. The interviewer practiced the interview and was aware that she may seek out information that confirms researchers pre-existing beliefs. Recall bias was avoided through organizing the interviews soon after the seminars. Selection bias was reduced through interviewing enough, here eight, students from three countries to ensure diversity of the population and the richness of experiences. The students interviewed were at various phases of their studies. Based on our critical reflection, the sample of participants represented the population.

Before starting our PhD education in international collaboration, we undertook a literature review on PhD education to recognize effective characteristics and possible in our case, combining of formal and non-formal learning, internationalization, collaboration, and communication plus professional activities, such as writing. These key characteristics for effective PhD education were introduced in our introduction chapter. Based on the literature review, we were not able to recognize alternative theoretical frameworks or perspectives that might interpret the data differently. One limitation in our study was contextual factors. It was clear the context of the seminars, such as, schedule, location, and services influenced the responses. However, the original idea was to design the context in such a way that it supported effective PhD education. Therefore, the results could be challenging to interpret and implement in the context of a traditional campus environment.

Limitations

This study collected data from a small number of PhD students participated in the PhD student's seminar series. Due to this, several limitations might affect the generalizability of the results – small sample size had a higher variability and less precision in responses, there were limitations on statistical methods that could be applied (incl. no normal distribution in data), the limitation that the sample did not adequately represent the whole population, it was difficult to draw meaningful conclusions about specific subgroups and small scale studies were harder to replicate to confirm whether the results were due to chance or represent a true effect.

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