EDITED BY MAIJA AKSELA, JUHA OIKKONEN & JULIA HALONEN

COLLABORATIVE SCIENCE EDUCATION AT THE UNIVERSITY OF HELSINKI SINCE 2003

New Solutions and Pedagogical Innovations for Teaching from Early Childhood Education to Universities

UNIVERSITY OF HELSINKI

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NEW SOLUTIONS AND PEDAGOGICAL INNOVATIONS FOR TEACHING FROM EARLY CHILDHOOD EDUCATION TO UNIVERSITIES

Edited by Maija Aksela, Juha Oikkonen & Julia Halonen

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FOREWORD AND COMPLIMENTS

The aim of science education is to strengthen the science competences. All branches of science belong to this division. By 2020, Finland aims to be one of the leading countries in science education. It is important to encourage children and youth to explore various branches of science, both in and outside of school. Science education is also an important part of universities' social role.[1] The development and strengthening of science education is a current topic and is important to society.[2] [3] [4]

At the University of Helsinki, science education is a part of societal interaction as well as research and teaching. It supports the university's strategic areas of focus in a versatile way. The Science Education Centre aims at acting as a global impactor and a pioneer and also a producer of new solutions and pedagogical innovations from early childhood education to universities. One important aim of science education is to promote sustainable development such as climate education, that follows the university's strategy. Research on science education creates a basis for the development and strengthening of science competences (see chapter 2 for more information). New, meaningful solutions and pedagogical innovations are needed in order to strengthen the science skills of youth and encourage them towards various sciences, as they are the makers of the future. Hands-on science education is a key to uniting different generations. Family operations have a central role in research and development projects in the near future. **Joy of insight and success for all!**

This book looks at the main operating models of a collaborative and interdisciplinary science education at the University of Helsinki since 2003 and the associated research from early childhood education to universities. It introduces new solutions and pedagogical innovations that have been developed in the Centre's operations, central publications and theses, on-going projects and future plans. Especially, examples of science education in **humanities, mathematics and natural sciences** are displayed as well as examples of **interdisciplinary** solutions.

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1 Opetus- ja kulttuuriministeriö (OKM). (2014). *Suomi tiedekasvatuksessa maailman kärkeen 2020: Ehdotus lasten ja nuorten tiedekasvatuksen kehittämiseksi.* Helsinki: opetus- ja kulttuuriministeriö. http://julkaisut.valtioneuvosto.fi/handle/10024/75252

2 Ahonen, P.-P. (2017). Tiedekasvatus on tärkeää yhteiskunnalle. http://www.aka.fi/fi/tietysti/blogit/kuulumisia-tieteesta/tiedekasvatus-on-tarkeaa-yhteiskunnalle/

3 Aksela, M. (2012). Tiedekasvatus ja sen tulevaisuus. Tieteessä tapahtuu, 30(4), 1–2. https://journal.fi/tt/article/view/6496/5343

4 Aksela, M. (2017). Lasten ja nuorten tieteestä innostuminen vahvistaa Suomen hyvää tulevaisuutta. Suomen Akatemian Tietysti.fi-blogi.http://www.aka.fi/fi/tietysti/blogit/kuulumisia-tieteesta/lasten-ja-nuorten-tieteesta-innostuminen-vahvistaa-suomen-hyvaa-tulevaisuutta/

The University of Helsinki is a global impactor that aims at promoting and supporting the following goals together with national and international partners and with the help of interdisciplinary and research-based operations of science education:

- Children and youth's science competences, enthusiasm towards science, and hobby-ism
- Everyone's awareness on the purpose of science and its various fields, its significance and results
- Everyone's scientific literacy or the ability to understand scientific phenomena connected to everyday life, to participate in discussions on current topics and to make decisions both on the personal and societal levels
- Teaching and learning of different fields of science/subjects on all levels from early childhood education to universities, and research concerning their teaching and learning
- Teacher education that trains encouraging and researching teachers for life-long learning (both pre-service and in-service education)
- Personal student recruitment
- National and international visibility and cooperation with different cooperation partners

Collaborative science education has been carried out systematically at the University of Helsinki since 2003 (see chapter 1 for more information). Today, the Science Education Centre[5] oversees it and represents the entire university. It represents the university in the LUMA Centre Finland[6] network that carries out a national purpose. Up until now, around 500 000 children, youths, family members, teachers and teachers-to-be have been a part of collaborative science events (both physical and virtual) and at the same time have participated in the creation and promotion of new solutions and pedagogical innovations through the research-based development of science education. This science education is considered to be important as well as encouraging, according to the received feedback as well as our research. It has also received national and international recognition for its operations (see chapter 1.1)

The operations are a good example of cooperation between the different fields of science and their representatives at the university and cooperation partners outside the university. Collaborative research and development operations, national and international cooperation and teacher education have been central characteristics of the operations since the beginning. Hundreds of people (researchers, doctoral students and students – future researchers and teachers from our university's different faculties) have participated in collaboration from the university with the

5 https://www.helsinki.fi/en/science-education

6 https://www.luma.fi/en/

administration. A number of national and international cooperation partners outside the university have taken part in promoting science education (see chapter 3 for more information). Cooperation with the private sector (e.g. industry) has been central since the beginning of the operations and it has brought new operating models in order to inspire people of the future towards science.

The forms of science education interest people both in Finland (Figure 1) as well as internationally. Up until now, about 2000 experts from Finland and other countries have visited the Centre. In 2017, there were visitors e.g. from Australia, China, France, Germany, Singapore, Slovenia and South Korea. Especially cooperation with China has been active.

Figure 1. The Education and Culture Committee from the Finnish Parliament along with the University Management of the University of Helsinki explored the developed activities of science education, especially new inspiring solutions and pedagogical innovations connected to science education in mathematics. (Pictures: Maija Aksela)

Research and development alignment of science education helps in directing the operations (see chapter 2). The purpose of science education at the university is to bring new research information in an inspiring way into teaching from early childhood education to universities, and to bring new openings. Its various non-formal forms of operation (such as science (LUMA) labs for schools at the university, see chapter 4 for more information) act as its central research and development environments.

New solutions and pedagogical innovations that have been developed based on the operations (for example learning environments, different approaches, teaching materials, courses) can be applied to teaching on various levels, also in the university level. Numerous theses (bachelor's, master's and doctoral) and scientific publications are integrated into the research-based development of science education. Versatile practical cooperation is performed actively with the City of Helsinki and in the nearby municipalities, with kindergartens, with different level schools, libraries and other environments for science education (such as Science Centre Heureka, the Museum of Technology). The purpose is to use these new openings broadly in different forums.

The science education operations focus on research as well as developing university education. Many new and developed solutions and pedagogical innovations are a part of education for future researchers and teachers (see chapter 5). In the training of future and in-service teachers, different forms of science education (for example instructing in a science lab for schools, science clubs, science adventures, science camps and science birthdays) act as inspiring ways to carry out training. New, interdisciplinary courses are developed into teacher education – also new kinds of forms, in which future teachers and school teachers study together. Other operators in the working life or international cooperation can be a part of them. Development can be carried out also in different learning environments (e.g. in libraries or science centres). Virtual, interactive MOOC courses are used even more as education and interaction forums for future teachers, teachers teaching on different levels and teacher educators of science education.

We would like to thank the University Management and its different faculties and directors of units and other administrations **for our successful cooperation**. We also thank members of executive boards and steering groups, directors and coordinators of the previous resource centres, the Centre's coordinators – the "hearts" of the operations, sponsors as well as all national and international cooperation partners. **A warm thank you** to the people who have been a part of making this book together (see Appendix 1 for more information). As our motto states, **together we are more!**

Science education needs resources to be able to develop. We kindly accept donations to our **Science Education Fund**[7], both from Finland and abroad, in order to enable new openings.

Together towards a great future!

In Helsinki on Valentine's Day, February 14, 2018

Prof. Maija Aksela	Prof. Juha Oikkonen	M.Sc. Julia Halonen
director	vice director	general coordinator

7 https://hy-yhteistyo.secure.force.com/helsinki/DonationPage

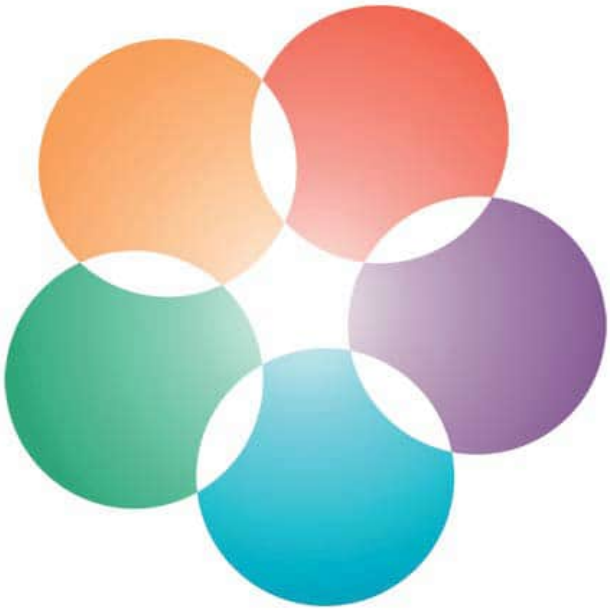

Figure 2. The light that shines in the middle of the LUMA-flower represents children and youths' **joy of insight and success**, the different colored petals represent the different fields of science, different levels and communality. The motto is: **Together we are more**!

1. THE SCIENCE EDUCATION CENTRE – A GLOBAL IMPACTOR AND A PIONEER

This chapter looks at the history of science education at the University of Helsinki, the current governance model, the objectives and thematic areas of focus as well as ways of execution. Science education is connected to all functions of the university: research, education and social interaction. The Science Education Centre aims at acting as a global impactor and a pioneer as well as a producer of new solutions and pedagogical innovations from early childhood education to the universities. The main purpose of science education at the university is to produce new research information in various and inspiring ways into teaching from early childhood education to universities, and to create new openings. Research on science education is connected to the Centre's functions (see chapter 2 for more information).

1.1 History

Science education and its research have been carried out systematically and communally at the University of Helsinki since 2003. They belong to the university's shared operations, act as a pioneer for science education in the future, and also supports current curricula on different levels and children and youths' hobby-ism. The current National Core Curriculum requires teachers and future experts have more direct interaction with universities and develop even more interdisciplinary, phenomenon-based knowledge, communal learning and new digital skills. Various faculties of the university operate together to strengthen the interdisciplinary science competences of our future experts and to encourage them towards science.

Before establishing the current Science Education Centre (in 2017) in honor of Finland100 centenary, the operations were spread out at the University of Helsinki. The national LUMA Centre (established in 2003) promotes education in mathematics, natural sciences and technology. AinO Centre (established in 2006) promoted education in the Faculty of Arts. In the near future, cooperation is aimed at being tightened with all the faculties at the University of Helsinki. During the years 2003–17, the Faculty of Science, Faculty of Biological and Environmental Sciences, Faculty of Arts and Faculty of Educational Sciences participated actively in collaboration. In Appendixes 2 and 3, you can find information on central operators, sponsors and cooperation partners.

Since 2003, the national LUMA Centre acted as an umbrella organization led by the University of Helsinki in order to direct cooperation between schools,

universities and the private sector[8] [9]. The central operators before the present Science Education Centre consisted of 7 resource centres spread around the university; BioPOP (in the Viikki campus), F2k (in the Kumpula campus), Geopiste (Kumpula campus), Kemma (Kumpula campus), Linkki (Kumpula campus), LumO (in the City Centre campus) and Summamutikka (Kumpula campus). For example, at the Department of Teacher Education (currently Faculty of Education), the development and operations contents of the LumO Centre were focused on grades 1–6. Before establishing the above mentioned LUMA Centre, different faculties and departments had various meritorious implementation models. At the beginning of the operations, the best models were collected together. You can find more information about the history and the operations from the Centre's website[10], where you can also find annual reports.

The Centre has received both **national and international recognition**: the director of the Centre was awarded with the University of Helsinki's J.V. Snellman award (in 2010), its LUMA lab for schools at the university, ChemistryLab Gadolin was awarded with an international Global Best Awards award (in 2014) and the Centre was recognized for its societal influence with the University of Helsinki's University in Society award, which was handed out for the first time at that time (in 2012)[11]. In addition, the popular online magazines (*Jippo, Luova* and *Kreativ*) published by the Centre received the annual state award for information publication in 2009.

Currently, the Science Education Centre represents the University of Helsinki in the national LUMA Centre Finland network[12]. The University of Helsinki has been in charge of its administration since it was established in 2013. LUMA Centre Finland has a national purpose and the Science Education Centre participates in it as a interdisciplinary participant.

When the Science Education Centre was established in 2003, the aforementioned resource centres of the LUMA Centre were not used as separate centres anymore, and instead the Centre operates as a **collaborative Science Education Centre** at the University of Helsinki. It has a mutual director, an executive board and a steering group as well as other administrative members (see figure 3 for further information).

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8 Vihma, L., & Aksela, M. (2014). Inspiration, Joy, and Support of STEM for Children, Youth, and Teachers through the Innovative LUMA Collaboration. In H. Niemi, J. Multisilta, L. Lipponen, & M. Vivitsou (Eds.), *Finnish Innovations and Technologies in Schools: A Guide towards New Ecosystems of Learning* (pp. 129–144). Rotterdam: Sense Publishers.

9 Aksela, M. K., & Vihma, L. (2015). Uudenlainen yhteisöllinen opettajankoulutus LUMA-ekosysteemissä elinikäisen oppimisen tukena. LUMAT, 3(6), 711–720. https://www.lumat.fi/index.php/lumat-old/article/view/91

10 http://www.helsinki.fi/en/science-education

11 https://www.sttinfo.fi/release?releaseId=2011412

12 http://www.luma.fi/en/

The implementation and development of science education is carried out independently in each field of science as well as in a interdisciplinary way. The executive board is directed by the Dean of the Faculty of Science and the executive board consists of members from each faculty that participates with the Centre. In the Centre's steering group, in addition to the representatives of the university, there is a number of cooperation partners. The coordinators of science education are specialists in their field of science and they act as instructors (e.g. of students) in carrying out operations, and they work under the director and the general coordinator. For the time being, the director of Science Education Centre is also the director of LUMA Centre Finland (since its establishment in 2013).

1.2 The Administration Model

The Science Education Centre unites the central persons from each field of science at the University of Helsinki. The current structure of the administration has been described in the figure below:

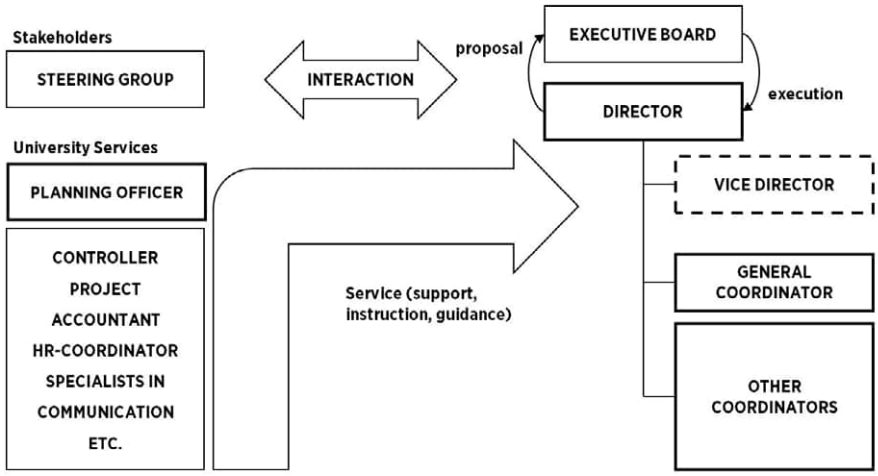

Figure 3. The administration model of the Science Education Centre since 2017. University Services helps in supporting the administration and the communication of science education.

At the moment, there are eight science education coordinators from four faculties (see the names of the coordinators in Appendix 2): one from the Faculty of Biological and Environmental Sciences, one from the Faculty of Arts (a university teacher of science education), one from the Faculty of Educational Sciences and five from the Faculty of Science, from which one is from the Department of Physics, one from the Department of Geosciences and Geography, one from the Department of

Chemistry, one from the Department of Mathematics and Statistics and one from the Department of Computer Science. As a team, they carry out the strategy with the Centre's director and the general coordinator. Usually the coordinators spend around 50% of their working hours with science education and its research. Most coordinators are doctoral students and they carry out research on science education.

1.3 The Aims and Thematic Focus Areas

Through diversified operations that aim to inspire children, youth and their families towards learning science, the University of Helsinki cooperates with a number of national and international partners. It researches and develops new pedagogical solutions and trains both future and in-service teachers of all levels for life-long learning in exploiting them in all kinds of teaching.

1.3.1 The Focus Areas

In the research and development and their associated operations, the following topics are the focus areas of the university and faculties in the strategy period from 2017–20 and as well the themes of the StarT operations:

- Digitalization (including data science; language technology; programming; robotics; technology around us)
- Globalization & sustainable development (including atmospheric sciences; urban studies; nature and the environment; mathematics around us)
- Matter and materials (including space research; materials research; nanoscience; stars and space)
- Sciences of life & aging and welfare (including well-being and health)
- The human mind in a changing world (including humane growth and development; home, culture, internationality; cultural and linguistic diversity; past, present and future)

1.3.2 Ways of Execution

The following topics are going to be researched and developed in the strategic period of 2017–20 in the operations of science education:

- Education that looks at phenomena as entities, and that integrates different fields (also fields of technology and arts)
- Pedagogically relevant exploitation using of modern technology
- Research-based and hands-on learning of sciences originates from the nature of a scientific process
- Taking into account the most novel innovations in science

Figure 4. The purpose of science education is to inspire a passion for the sciences with the help of research and development operations produced in the Centre. (Picture: Sofie Jokinen)

2. NEW SOLUTIONS AND PEDAGOGICAL INNOVATIONS THROUGH RESEARCH AND DEVELOPMENT

This chapter looks at the current operating model and alignments of science education at the University of Helsinki. The operations are connected to all functions of the university: research, teaching and societal interaction. The Science Education Centre aims at acting as a global impactor and a pioneer. It produces new solutions and pedagogical innovations from early childhood education to universities **both in a interdisciplinary and a discipline specific way.** The aims are described in more detail in the foreword section.

2.1 The Operating Model

The Science Education Centre acts in the university's organization as a high-grade specialist Centre that serves and coordinates in carrying out research and development of science education. The executive board of the Centre has verified the alignments of the research and development operations in 2017. Here, all planning and execution takes place, both in the short and long-run.

New solutions and pedagogical innovations (such as novel and meaningful learning environments, methods and teaching materials etc.) are developed on the basis of research in various non-formal learning environments. These innovations are spread out through collaboration with other cooperation partners, for example by training future and in-service teachers and by publishing in different media. Developed solutions can be applied to formal education and learning in different school levels.

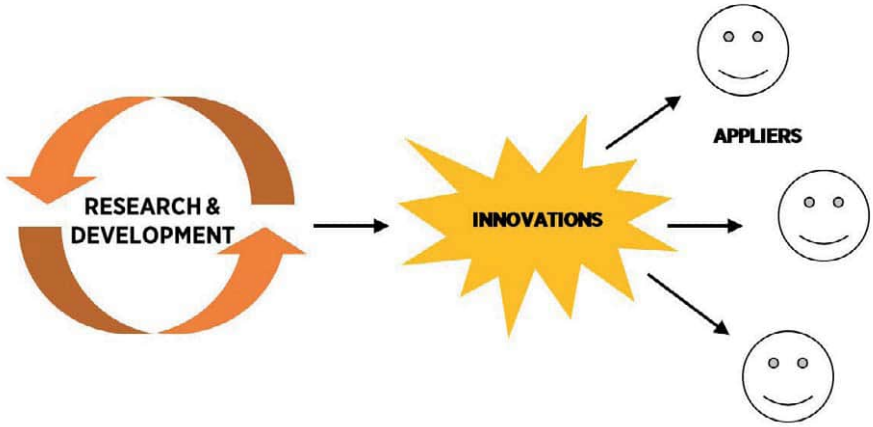

Figure 5. The development and research operations of science education create new solutions and pedagogical innovations for the Finnish society to use, but they can also be spread around globally with the help of educational exporting.

By its nature, the Centre is a communal organization for research, development and experts. Its purpose is to share all of its output with its members, and by doing this it strengthens the science competences.

2.2 Non-formal Learning Environments as Research and Development Environments

The purpose of the university's science education is to create new research information in inspiring and versatile ways into teaching from early childhood education to universities, and to create new openings. Its various non-formal and informal forms of operation act as major environments for research and development, for example science labs (LUMA labs) for schools at the university (see chapter 4 for further information), science clubs, science camps, science parties, science events, carrying out science at home, activities taking place in the nature, and science adventures (see chapters 6 and 7). The aforementioned environments may be partly or entirely virtual. Cooperation is carried out with the educational administration, the private sector, Science Centre Heureka, museums, libraries and with different organizations and associations.

At the learning environments, there are studies performed focusing on children, youth and their parents (including their science competences), on students studying to be teachers or in-service teachers and instructors (their learning, training or how they act in learning environments), and on cooperation between different participants. Based on this research, new solutions and pedagogical innovations from early childhood education to universities are being created (see Figure 6).

Forms of operations that have been developed up until now, are being introduced in chapters 3–8.

Several different research methods are used in development especially the iterative method/analysis of design-based research (DBR) (see figure 6). Design-based research produces not only new theoretical information and scientific publications, but also new and useful solutions and pedagogical innovations such as learning environments, methods or teaching material, which support the Centre's idea of main activity. Based on the received findings, it is possible to develop previous and new forms of operation. Also, formal school education research and teacher education research or development suggestions from the cooperation partners are taken into consideration in science education and in its research.

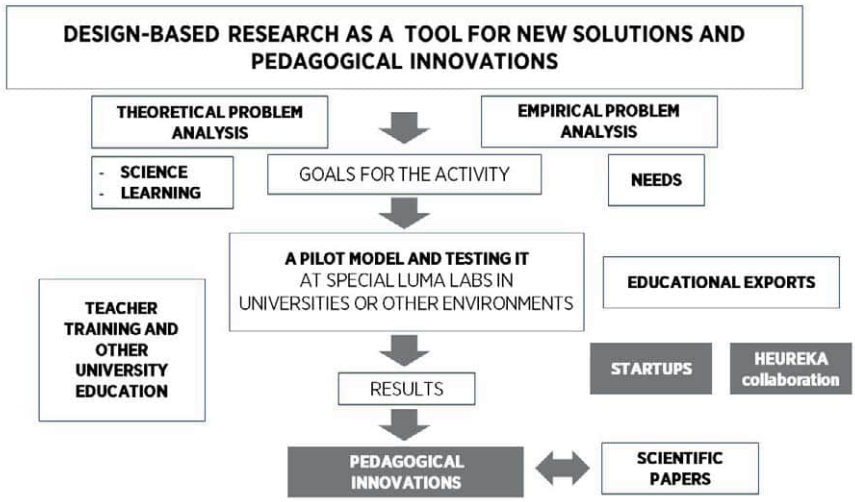

Figure 6. Design-based research is one of science education research methods. Numerous studies are conducted mainly in the form of different level theses (e.g. masters or doctoral level). For example, an ongoing design-based research is taking place on the subject of significant science education in mathematics and programming (Pulmaario project). Newly developed solutions and pedagogical innovations are applied to university teaching and its teacher education as well as in the operations of cooperation partners such as science centres. The theoretical information learned from the research is used to make scientific publications. Pedagogical innovations have led to cooperation with companies, and educational exporting.

3. NATIONAL AND INTERNATIONAL COLLABORATION IN RESEARCH AND DEVELOPMENT

The Science Education Centre cooperates with national and international partners and aims at reaching the assigned goals together. The motto of the operations is "**Together we are more**". Through this collaboration, it is possible to learn from each other and together a stronger impact can be made. This chapter looks at principles of research connected to science education and gives examples of a couple of significant national and international projects, in which we have participated or are participating in momentarily.

3.1 Research and Development Together

The Science Education Centre gathers around people, who carry out research and development of science education at the University of Helsinki. The director of the Centre is in charge of directing the research and development operations according to the alignments verified by the executive board. Professors, university lecturers and research doctorates, who are interested in science education of various fields of science, participate in planning research and theses, executing them and instructing them together with the director. Scientific publications are comprised of research together. Numerous Professors, university lecturers and research doctorates are also members of the Centre's steering group (see appendix 2).

Research and development is often carried out in national and/or international projects (see chapters 3.2 and 3.3). One of the international cooperation partners is LUMA China Center in Beijing Normal University. Researchers and doctoral students actively take part in national and international conferences (e.g. LUMAT symposium). International research cooperation is being strengthened by visiting different universities and science centres abroad and by hosting visits of foreign researchers at the University of Helsinki. Over the years, around 2000 foreign visitors have visited our Centre from Australia, China, Denmark, Estonia, Germany, Greece, Japan, the Netherlands, Norway, Portugal, Russia, Singapore, Slovenia, South Korea, Sweden, Turkey, the United Arab Emirates, and from the United States.

Figure 7. Cooperation is carried out with a number of national partners. Long-term cooperation has occurred with the Development Centre Opinkirjo and TEK (Academic Engineers and Architects in Finland) in Finland's oldest science competition Tutki-Kokeile-Kehitä[13] ("research – test – develop") in the organizing of the competition, communications and judging. The Centre has arranged numerous competition events at the University of Helsinki. (Picture: The University of Helsinki Science Education Centre)

3.2 Examples of National Projects

National cooperation of the Science Education Centre is executed through the LUMA Centre Finland which is a network of the 13 regional LUMA Centres that are operated by 12 Finnish universities.[14] Some Finnish applied universities also operate within the regional centres. During the years 2017-20, a national task that has been laid down by the Ministry of Education and Culture will be carried out together. It consists of six sections that include:

13 https://tukoke.tek.fi/

14 http://www.luma.fi/en/

- international cooperation is being promoted and another aim is to increase national funding of operations
- inspiring activities on science education and online courses that are being developed together, are offered to children and youth, these support e.g. student recruiting on the university level
- conducting research connected to the operations that brings more information in order to develop the functions, and to increase interests in different fields and to produce new solutions and pedagogical innovations
- teachers' professional skills are being developed and supported, so that they would form a continuum from teacher's basic education, and onwards
- phenomenon-based teaching and interdisciplinary learning that are underlined in the National Core Curriculum should be supported and developed through the national and international StarT operating model since early childhood education, and to inspire children and youth towards studying science through new approaches
- science and technology classroom (LUMA labs for schools) operations should be developed and strengthened all over Finland

In the following part, a couple of interdisciplinary collaborative projects are given as examples of national operations: the LUMA FINLAND development program (chapter 3.2.1.) and the collaborative StarT program (chapter 3.2.2.) and an example of a discipline specific national project (luku 3.2.3.). Research and development are a crucial part of the aforementioned projects.

3.2.1 The LUMA FINLAND Development Program: New Ideas for Teaching Mathematics, Natural Sciences and Technology

The LUMA FINLAND development program[15] (2014–2019) has been funded by the Ministry of Education and Culture as a nationally significant collaborative project. There, a number of new pedagogical solutions and innovations are produced for teaching from early childhood education to different levels of primary education. At the moment, there is ongoing in-service training for teachers in them during 2017–19. It is free of cost to the teachers. A steering group directed by the Ministry of Education and Culture monitors and instructs the program. The director of the program, Professor Maija Aksela and Coordinator Saara Lehto are members of the steering group on behalf of the University of Helsinki.

The purpose of the program that is being implemented by the LUMA Centre Finland network is to increase 6–16-year-old students' interest in studying

15 http://suomi.luma.fi/

mathematics and natural sciences, to encourage students to choose courses on these subjects in upper secondary school and in vocational education, and to increase the skills in science and technology in order to increase the number of skilled persons in these fields. The program brings new methods into teaching that are based on most novel research and that have been tested and designed with the help of teachers. The work in schools is supported by producing learning materials that can be used freely, and by training teachers on using different approaches, environments and material. A bilingual program supports teachers in using the national core curriculum that was completed in 2016 (in the form of support material and training sessions). This is based on new research information on new learning environments, online learning materials and ways of learning.

Development has occurred in 37 projects all over Finland in cooperation with schools or kindergartens and teachers as well as other partners. The produced material has been published for everyone to use, the material is partly in Finnish and partly in Swedish. In order to support the usage of material and developed operating models, free training has been offered to teachers since 2017. The training sessions that run till the end of 2019 (including virtual MOOC courses) can be found from the program's website. A network of LUMA contact persons from municipalities all over Finland has been built in the program.

In the program, there are a number of research and development projects in different universities. The University of Helsinki is a part of this program with eight different projects (you can find more information on each of the projects from their websites as well as material for teaching):

1. A Good Question![16]
2. Everyday Life Phenomena[17]
3. From Training to School[18]
4. Innokas! – Let's Be Enthusiastic and Innovate Together[19]
5. Meaningful Mathematics[20]
6. Programming for Everyone[21]
7. Science and Mathematics in Society: Interdisciplinary Cooperation with Companies[22]
8. Understanding in Problem Solving[23]
9. Wonder and Find Out: Pre-school Children's Science Process Skills[24]

16 http://suomi.luma.fi/hankkeet/hyva-kysymys/

17 http://suomi.luma.fi/hankkeet/arkielaman-ilmioita/

18 http://suomi.luma.fi/hankkeet/koulutuksesta-kouluun/

19 http://suomi.luma.fi/hankkeet/innokas-innostutaan-ja-innovoidaan-yhdessa/

20 http://suomi.luma.fi/hankkeet/mielekas-matikka/

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22 http://suomi.luma.fi/hankkeet/matematiikka-ja-luonnontieteet-yhteiskunnassa-yhteisollista-opiskelua-tyoelaman-kanssa/

23 http://suomi.luma.fi/hankkeet/ymmarrysta-ongelmanratkaisuun/

24 http://suomi.luma.fi/hankkeet/tutki-ja-tuumaa-esikoululaisten-tutkimisen-taidot/

Figure 8. StarT science festivals all around Finland act as collaborative and inspiring learning environments. In these events, the creativity and know-how of children and youths is crucial. They present innovative projects and learn from each other. In addition, the representatives of learning communities (e.g. schools, kindergarten, science clubs) present the best educational practices related to the implementation of phenomenon-based and interdisciplinary learning in pedagogical cafes and get ideas for the implementation of the school-specific and national curricula in their learning community. These events act also as new models for teachers' in-service training. In the picture, children and youths from the Uusimaa region are attending a StarT science fair in Heureka Science Centre in 2017. (Pictures: The University of Helsinki's Science Education Centre).

At the moment (during 2017–19), there is broad, on-going in-service training for teachers on the above-mentioned projects. Most of the them are carried out as interactive online courses (MOOCs), in order for it to reach as many as possible. The program consists also of evaluation research and various research, including theses.

3.2.2 The StarT Program – Interdisciplinary Collaboration

Another nationally significant development program that brings new approaches into teaching is the interdisciplinary and collaborative **StarT operating model**[25], which was established as a collaborative project of the LUMA Centre Finland network in honor of Finland's centenary. The project is aimed all the way from early childhood education to second degree education. Several theses are connected to it and scientific publications are written in cooperation with different universities on its various themes. Professor Maija Aksela is the director for the StarT program. Outi Haatainen has worked as the national project manager and Essi Purhonen has worked as the international project manager from the University of Helsinki. Tens of cooperation partners such as organizations and companies work together with StarT (see StarT's website). In 2017, the president of Finland, Sauli Niinistö, acted as the patron for the program. A number of significant Finnish directors (e.g. the director general of the Finnish National Agency for Education) and specialists (see the names from the website) act as mentors for StarT. It will be carried out at least until the summer of 2020 as part of the national task of LUMA Centre Finland.

New collaborative forums for learning have been developed at StarT with the assistance of the entire LUMA Centre Finland network: **StarT Days** are various events organized by the participating learning communities to share learning in their own community, **StarT festivals** are regional events, science fairs, organized all around Finland by the LUMA Centers together with local partners, and the **StarT Gala** is an annual award ceremony including national and international encouragement prizes. Awarded projects and assessment criteria can be found on the StarT website.

StarT supports the use of interdisciplinary learning modules that follow the new core curriculum (e.g. with mathematics, arts or languages) and helps in developing new solutions on relevant interdisciplinary and collaborative learning, on the basis of research. StarT is a part of the curriculum for learning communities. The entire school or kindergarten with its cooperation partners participates together in StarT programming. Learning happens in StarT by being creative and working together on projects and by sharing the joy of learning and good educational practices in

25 https://start.luma.fi/en/

collaborative events both nationally and internationally (for example through a **virtual online poll**). This project-based learning that follows the StarT concept, can be carried out also in clubs or at home (see **StarT Clubs** in chapter 6).

The themes of StarT projects in 2017–18 are: mathematics around us; nature and the environment; well-being; stars and space; home, culture and internationality; this works: mobile toys, and technology around us. **A material bank** that is updated constantly has been comprised in order to support learning, with the help of Technology Industries of Finland Centennial Foundation. Together with Aalto University, The Science Education Centre has supported kindergartens and primary schools in carrying out StarT projects in the Uusimaa region.

Satojen vinkkien StarT-materiaalipankki projektioppimisen tueksi

StarT avaa kaikille iloksi ja hyödyksi tukimateriaalit, joissa on satoja vinkkejä projektioppimisen aloittamiseksi. Lisäksi tukimateriaaleissa on tietoa projektien toteuttamisesta yleisellä tasolla, arvioinnista sekä ilmiölähtöisyydestä ja eheyttämisestä. Materiaalit on jaoteltu teemoittain:

1. Matematiikkaa ympärillämme
2. Luonto ja ympäristö
3. Hyvinvointi ja terveys
4. Tähdet ja avaruus
5. Koti, kulttuuri, kansainvälisyys
6. Tämä toimii
7. Teknologia ympärillämme

Muita materiaalipankkeja löytyy tämän linkin takaa.

Yhteistyökumppaniemme tarjoamia työkaluja projektien tueksi.

Figure 9. StarT's materials that include videos, offer support for interdisciplinary project-based learning as a part of implementation of the national and school-specific curricula in learning communities. On the website, the material has been classified according to school level. You can also find a short video on the website of StarT about the operating model.

Learning in StarT occurs in **international interaction**: 36 countries participated in 2017. The StarT Estonia collaborative project was launched in December 2017. In 2017, the gala was organized as a part of the national and the international LUMAT symposium, at the Great Hall of the University of Helsinki's main building. National and international awards were given out by the Minister of Education,

Sanni Grahn-Laasonen (see Figure 10), by Jukka Kola, the Rector of the University of Helsinki, along with other representatives of cooperation partners.

Figure 10. In the national and international StarT gala, internationally distinguished teams consisting of children and youths, and best educational practices of learning communities are annually awarded the *International LUMA StarT (Education) Award*. In 2017, **Sanni Grahn-Laasonen**, the Minister of Education, handed out the main awards. Various encouraging awards are given also nationally and regionally by universities and their cooperation partners.

3.2.3 Discipline Specific Collaborative Project on Molecular Modelling

Nationally, cooperation is carried out in order to promote education in the various fields of science. An example is a nationally significant development and research project on **Computer Assisted Molecular Modelling in School Teaching** (2008–2011). During this project, as a new opening in the research of chemistry, molecular modelling was made a part of Finnish school education and teacher education. It was carried out as a part of chemistry teacher education and science education at the University of Helsinki. Cooperation took place with chemistry teacher education in Department of Chemistry at the University of Jyväskylä. The project was funded by the Finnish Cultural Foundation.

In Computer Assisted Molecular Modelling in School Teaching project:

- new pedagogical solutions and approaches into chemistry teaching were developed nationally and internationally in cooperation with innovative school teachers, and most novel research information through the newest research
- mentors of molecular modelling were trained all over Finland. They acted as instructors on their own areas and offered support
- open learning material that supports the using of molecular modelling, was produced online for teachers
- research was conducted concerning the opportunities and its effectiveness in the learning and teaching of chemistry.

The research concerning the project was turned into several publications, and also a doctoral dissertation[26] [27] [28] [29]. The acquired results have been used broadly in several institutions, in teacher education and also in one of the LUMA labs (for schools) of the Centre, ChemistryLab Gadolin[30]. In 2017, know-how was spread out internationally in the form of a nonfiction book that was written in English[31].

26 Aksela, M., & Lundell, J. (2008). Computer-Based Molecular Modelling: Finnish School Teachers' Experiences and Views. Chemistry Education and Research, 9(4), 301–8. https://doi.org/10.1039/B818464J

27 Aksela, M. Lundell, J., & Pernaa, J. (2008). Molekyylimallinnuksen mentoreita kemian opetuksen ja oppimisen tueksi. Teoksessa J. Välisaari & J. Lundell (toim.), *Kemian opetuksen päivät 2008: Uusia oppimisympäristöjä ja ongelmalähtöistä opetusta* (s. 59–68). Jyväskylä: Jyväskylän yliopisto.

28 Pernaa, J., Aksela, M., & Lundell, J. (2009). Kemian opettajien käsityksiä molekyylimallinnuksen käytöstä opetuksessa. Kirjassa M. Aksela & J. Pernaa (toim.), Arkipäivän kemia, kokeellisuus ja työturvallisuus kemian opetuksessa perusopetuksesta korkeakouluihin – IV Valtakunnalliset kemian opetuksen päivät (s.195–204). Helsinki: Yliopistopaino. https://www.helsinki.fi/sites/default/files/atoms/files/verkkojulkaisu_kop2009.pdf

29 Pernaa, J. (2011). Kehittämistutkimus: Tieto- ja viestintätekniikkaa kemian opetukseen. Helsinki: Helsingin yliopisto. (PhD thesis) http://urn.fi/URN:ISBN:978-952-10-7291-8

30 https://www.helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin

31 Pernaa, J., Aksela, M., & Ghulam, S. (2017). Introduction to Molecular Modeling in Chemistry Education. Jokioinen: e-Oppi Ltd. & Edumendo Publishing. http://bit.ly/immice

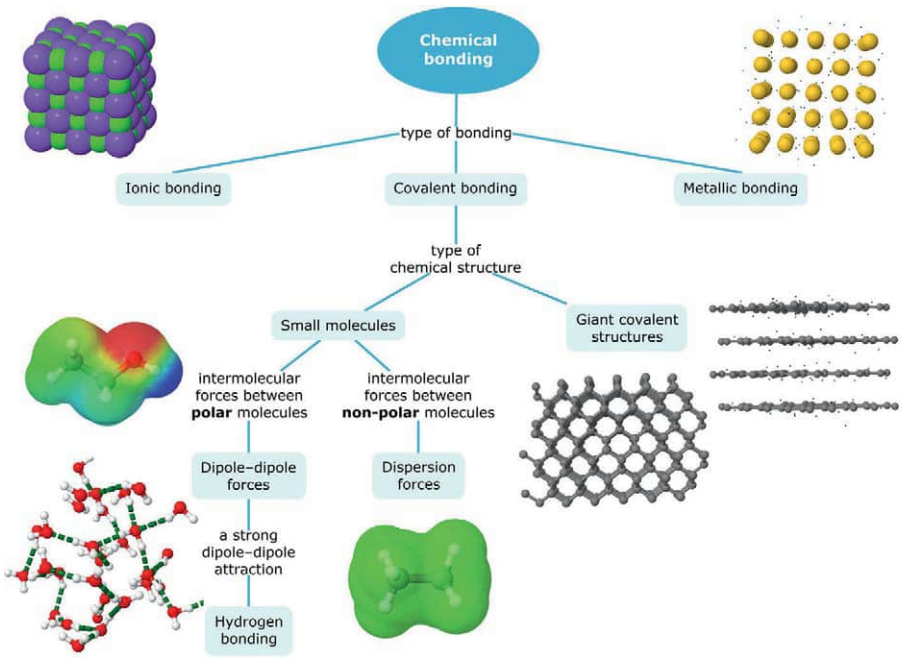

Figure 11. An example of computer assisted molecular modelling. The use of these models increases the understanding of terminology and phenomena in chemistry, and it can be used for example alongside practical work.

3.3 Examples of International Projects

The Science Education Centre aims at acting as a global impactor according to the university's strategy. The aim of development and promotion is to be able to have interdisciplinary interaction with other countries and to learn from others during the interaction. The Centre has participated in the European **Scientix** community and **Science on Stage** network. The director of the Centre has been a representative of Finland in the ALLEA organization's[32] science education work group since 2010.

32 http://www.allea.org/

Figure 12. The Science Education Centre aims at promoting youths' science skills in various ways (see chapter 7 for further information). In 2011, an international, interdisciplinary science competition *European Union Contest for Young Scientist* was organized in Helsinki. The Science Education Centre was one of the major cooperation partners there. (Picture: Sakari Tolppanen)

In addition to the above-mentioned StarT project (see chapter 3.2.2), we have participated or are participating currently in the following international projects that have brought new approaches into teaching (listed in alphabetical order): the Nordic **ActSHEN** project (chapter 3.3.1), the EU project: **COMBLAB** (chapter 3.3.2), the EU project: **Designstem** (chapter 3.3.3), the EU project: **LINKS** (chapter 3.3.5), which is a collaborative project of the entire LUMA Centre Finland network. In addition, sustainable development has been promoted with the help of virtual operations (chapter 3.3.4).

3.3.1 The ActSHEN Project: A Model for Teaching Sustainable Development in the University Level

Action for Sustainability in Higher Education in the Nordic region (**ActSHEN**)[33] is a Nordic cooperation and research project that was active during 2013–17, where a model for the university level was established in order to support sustainable

33 http://blogs.helsinki.fi/action-for-sustainability/

development[34] [35]. NordPlus has been funding the project, and the University of Helsinki has been a part of the project with the University of Iceland, Stockholm University, Uppsala University, Telemark Research Institute and the Iceland Academy of Arts.

New approaches have been produced in the project on education concerning sustainable development (sustainability education). These approaches have been applied to various participating institutions and to a course "Sustainable development in teaching" for future teachers at the University of Helsinki. In the developed models, a student's active participation is crucial. Students participate by planning and implementing the course each year, and it has been carried out in a interdisciplinary way. Circular economy, climate change and sustainable food have been themes of the course. Approaches include interactive lectures as well as projects, excursions, discussions, blogs and drama.

3.3.2 The COMBLAB project: Inquiry-based Science Teaching with Microcomputer-based Laboratory Activities

The EU-funded **COMBLAB** project (2012–14) was carried out in cooperation with research experts from the Universities of Spain, Austria, Slovakia, Czech Republic and Finland. The aim of the project was to create new material that utilizes microcomputer-based laboratory equipment in science teaching. The focus group was lower secondary school students who study natural sciences like biology, chemistry and physics. The material was developed communally with university researchers and teachers. The teachers who took part in the project were also trained to use the material. The effectiveness of some of the activities and the whole project was studied[36] [37]. The study that was accomplished at the University of Helsinki in 2011 was used as background information[38]. The international ISSE-conference was held at the University of Helsinki in 2014 at the end of the project.

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34 Heiskanen, N., Käyhkö, J. & Virtanen, H. (2017). Students as teachers: A student point of view. LUMAT-B, 2(3), 91–93. https://www.lumat.fi/index.php/lumat-b/article/view/275

35 Herranen, J., Tolppanen, S., Vesterinen V.-M. & Aksela, M. (2017). Students as teachers:Design of a student-led course on sustainability education. LUMAT-B, 2(3), 87–90. https://www.lumat.fi/index.php/lumat-b/article/view/274

36 Tolvanen, S., & Aksela, M. (2013). Mittausautomaation hyödyntäminen tutkimuksellisessa kemian opiskelussa. (Using microcomputer-based laboratory equipment in inquiry-based chemistry education). *LUMAT*, *1*(4), 379–386.

37 Tolvanen, S., Aksela, M., Guitart, F., & Urban-Woldron, H. (2014). Research-based future science teacher training on using ICT-enhanced inquiry activities. In C. P. Constantinou, N. Papadouris & A. Hadjigeorgiou (Eds.), *EBook Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning. Part 4 (Eds. G. Olympiou & P. Marzin-Janvier)*, (pp. 181–190). Nicosia, Kypros: European Science Education Research Association. ISBN: 978-9963-700-77-6.

38 Aksela, M. (2011). Engaging students for meaningful chemistry learning through Microcomputer-based Laboratory (MBL) inquiry. *Educació Química EduQ*, 9, 30–37.

The purpose of the produced research-based learning materials is not only to support the student to use and apply previously learned information, but also to encourage them in producing new information. By using inquiry-based methods, the students plan the arrangements of the experiment, analyze the measurement data, evaluate the results and make a small report. The examples of the activities that are connected to everyday life include, for example: the effectiveness of heartburn medication, the copper concentration of a brass nail, the temperature change in coffee, and emissions research with a spectrophotometer in order to understand how a greenhouse works. Comprehensive learning materials that include material for teachers, can be found online[39] in seven different languages. Most experiments are used in teacher education and the material can be found in the ChemistryLab Gadolin[40].

Figure 13. Utilizing modern technology (for example: microcomputer-based laboratory equipment, molecular modelling and other modern technologies) is one area of research in science education. The activity of spectrophotometer in the picture is developed for the use of school visits. (Picture: Veikko Somerpuro)

39 http://comblab.eu/en

40 http://www.helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin

3.3.3 The Designstem Project: LUMA Education in the Context of Art

Using arts and drama in teaching is one area of research in science education[41]. For example, by integrating design and stem education (natural sciences), it is possible to receive new and inspiring methods into teaching. It unites creativity and the solving of practical problems.

The Designstem[42] (2016–19) is an on-going project of science education, which aims at developing online learning materials that unite design and natural science, such as games, mobile applications or interesting e-learning materials. The target group consists of 15–19 year-olds who study LUMA subjects and 15–25 year-old students who study design. 10 European cooperation partners participate in the project. In addition to Finnish partners, there are cooperation partners from Estonia, Germany, Greece, the Netherlands and Portugal.

3.3.4 A Virtual Project on Science Education in Order to Promote Sustainable Development

The promotion of education for sustainable development (ESD) is one of the central focus areas of the Science Education Centre. Research is conducted on the topic, as well as theses for example doctoral dissertations[43] [44].

New virtual operating models for sustainable development and its promotion both for youth and teachers have been researched and developed in a virtual science education project. Up until now, three international sub-projects have been carried out: (i) ***Millennium Youth Course: Sustainable Energy***, that is aimed for the youth, (ii) ***Sustainable Energy in Education: International MOOC for STEM teachers***, that is aimed for teachers and (iii) ***International Teachers' Climate Change Forum***, that is also aimed for teachers. Doctoral dissertations and know-how of doctoral students in

41 Esim. Turkka, J., Haatainen, O., & Aksela, M. (2017). Integrating art into science education: a survey of science teachers' practices. *International Journal of Science Education*, *39*(10), 1403–1419. DOI: 10.1080/09500693.2017.1333656

42 http://bit.ly/2DdLOfe

43 Juntunen, M. (2015). Holistic and Inquiry-Based Education for Sustainable Development in Chemistry. Helsinki: University of Helsinki. http://urn.fi/URN:ISBN:978-951-51-1231-6

44 Tolppanen, S. (2015). Creating a Better World: Questions, Actions and Expectations of International Students on Sustainable Development and Its Education. Helsinki: University of Helsinki. http://urn.fi/URN:ISBN:978-951-51-1312-2

science education has been exploited in designing the project and carrying out the project.

In the ***Millennium Youth Course: Sustainable Energy*** project, a new open online course (MOOC) aimed for youth all over the world, was developed together with the Aalto University and with the Technology Academy of Finland (TAF). The aim of the course was to give a cross-section of how the production of energy and its usage could be made more sustainable, to offer ideas, support and encouragement on how to bring it up in teaching, to increase interaction between specialists, to share good practicalities internationally and to support cooperative learning, and to bring forth Finnish know-how of the field and study opportunities. An international scientific paper of its significance for students[45] has been published. The course[46] was piloted in Fall 2015. University students also took part on this course.

In the project *Sustainable Energy in Education: International MOOC for STEM teachers* that was aimed for pre-service education and in-service training, an international online course was developed in the Spring of 2016: ***Sustainable Energy in Education: International MOOC for STEM teachers***[47] (worth 1 ECTS). Research information and material that was received from a MOOC course aimed at youth, was used to develop the course. The course was aimed at teachers at the lower and upper secondary levels, future teachers, teacher trainers and other specialist in education around the world, who were interested on the topic. In the Spring of 2018, a publication based on the research data collected during the course, is going to be published. Based on this research, virtual training for science education is still being developed.

In Fall 2016, an international virtual project on the teaching of climate education ***International Teachers' Climate Change Forum***[48] was carried out. Here, teachers of various school levels from all around the world applied for performers. The chosen teachers prepared short videos of their own teaching ideas and experience. The other participants of the symposium first watched the videos and then communally discussed what they had seen, with the help of instructors. Themes included: "Eco anxiety", "An online MOOC on climate change", "Examining sea-level rise in the lab" and "Increasing nature connectedness". Material and videos were available for everyone to use and they can be found on the website. They are currently used in training future teachers. The training was implemented with a funding from the Magnus Ehrnrooth Foundation.

45 Aksela, M. K., Wu, X., & Halonen, J. E. (2016). Relevancy of the Massive Open Online Course (MOOC) about Sustainable Energy for Adolescents. Education Sciences, 6(4). DOI: 10.3390/educsci6040040. https://helda.helsinki.fi//bitstream/handle/10138/174338/education_06_00040.pdf

46 https://mooc.helsinki.fi/course/view.php?id=6

47 https://mooc.helsinki.fi/course/view.php?id=20

48 https://www.luma.fi/en/event/international-teachers-climate-change-forum/

3.3.5 The LINKS Project: New Approaches in Teacher Training

In the EU-funded LINKS project (*Learning from Innovation and Networking in STEM – science, technology, engineering and mathematics*)[49] during 2016–19, research-based primary education and teaching of LUMA subjects (math and science) in the upper secondary level is promoted through the training of teachers and teacher educators of LUMA science education.

The project is carried out by experts from Austria, Finland, France, Italy and the United Kingdom. The participating 9 communities are a part of national networks in their own countries, and several of them are also involved in coordination efforts. All in all, they represent 120 local or regional providers of in-service education.

LINKS is a part of the LUMA Centre Finland network's operations. The University of Helsinki's Science Education Centre represents Finland in LINKS together with the LUMA Centre from the University of Eastern Finland. Here, the purpose of the University of Helsinki is to promote operating models of school and company cooperation in pre-service teacher training and to organize the farewell conference of LINKS in Helsinki.

49 http://www.luma.fi/keskus/hankkeet/links/

4. LUMA LABS FOR SCHOOLS AS ENVIRONMENTS FOR LEARNING, RESEARCH AND DEVELOPMENT

4.1 General

The aims of science education operations are promoted in operations concerning science classes or labs for schools at universities (often called **LUMA labs**) in cooperation with the faculties at the university as well as with specialists outside the university (e.g. specialists in the private sector). Science classes or labs -learning environments, of which there are momentarily **six** all over the university (since 2008), are an example of pedagogical innovations of the science education operations at the University of Helsinki. The thematic focus areas of research at the university and ways of execution are central in the operations of LUMA labs (see chapter 1.3.1 and 1.3.2). The purpose is to strengthen and broaden the operations in the future, at the University of Helsinki. In the near future, it is going to be strengthened in the form of a mutual booking calendar. The operations are also a part of LUMA Centre Finland's national purpose.

The **four purposes** of science classes or labs at the university, in the heart of science education of the Centre include:

(i) to act as inspiring learning environments for children and youth at the authentic facilities of the university, and to support current and future national core curricula (yearly nearly 10 000 children and youth visit the LUMA labs in different forms of science education. At the same time, they are an important form of recruitment for the university, in which through participating activities, children and youth are inspired towards sciences.)

(ii) to act as research and development environments for science education (visiting children and youth, teachers, family members and cooperation partners participate in various projects, and therefore promote the development of new solutions and innovations, scientific publications and theses. At the moment, there is ongoing general study on the pedagogical usage of all science labs.)

(iii) to act as an encouraging learning environment for pre-service teacher education of future teachers and/or in-service training of teachers on different levels (there are various learning exercises on basic teacher education and its research that are connected to the operations of the LUMA labs; in in-service training, different implementation models are developed together with teachers; a part of these is in cooperation with basic teacher training.)

(iv) to act as a collaborative, operational environment in cooperation with national and international persons (researchers, the private sector, different organizations etc.) and to create new openings and develop solutions together for significant science education

In the following part, six science classrooms/labs at the university are presented in alphabetical order and their central forms of operation are described in detail. The first science lab, ChemistryLab Gadolin, was established at the University of Helsinki in 2008, together with the private sector (e.g. industry).

Currently there are altogether 14 innovative science labs (LUMA labs) in the universities in Finland (a part of the operations of LUMA Centre Finland), and diverse cooperation occurs with them. Also, international cooperation in the science lab operations is about to begin.

4.2 BioPop – Science Education in Biological and Environmental Sciences

BioPop is a LUMA lab that is located at the Viikki campus of the University of Helsinki. Its purpose is to promote science education on biological and environmental sciences. It was established in 2007.

BioPop produces new solutions and pedagogical innovations in the science education of biological and environmental sciences. It offers a possibility for teachers on all school levels to bring their students to get to know new pedagogical innovations and the inspiring world of the field in an authentic teaching and research environment. It is possible to carry out modern inquiry in the science lab that cannot be easily performed in school teaching. New teaching materials that have been developed in the BioPop lab are open to all teachers.

When visiting the BioPop lab, it is possible to perform all kinds of inquiry-based work, explore authentic research laboratories, meet researchers, learn new things on field trips and to learn about the field of biology and its studies. The purpose of new innovations and methods is to support the student's understanding and interest towards biological and environmental sciences. During the visits, the use of inquiry-based learning is designed to encourage the students to think by themselves and to gain insight themselves. Student teachers are actively participating in science labs, they instruct visitors and at the same practice their future professions. In 2017, nearly 2000 visitors visited the BioPop lab.

Figure 14. BioPop science lab (LUMA lab) is the only lab for schools at universities in Finland that itself specializes in science education on biological and environmental sciences. In the lab, it is possible to perform new and modern inquiry-based laboratory work in an authentic laboratory and to receive joy of insight and success, which strengthens the science competences.

4.3 F2k – Science Education in Physics

The science lab for physics, F2k teaching laboratory was opened on the Kumpula campus in 2010. Before it was opened, the operations were known as Kondensaattori ("Capacitor"). The present name, F2k, reflects the fact that the operations are based on modern physics and its applications.

F2k produces new and meaningful solutions and pedagogical innovations for science education in physics. Its purpose is to support and promote motivating and diverse teaching and learning of physics, in all levels of primary school and as well in secondary school. An aim is also to support hobbyism not only among children and youth, but also among adults. Inquiry-based teaching of physics is at the heart of everything. F2k cooperates closely with teacher education in physics (a part of the new *Degree Program for Subject Teachers in Mathematics, Physics and Chemistry*) and its research.

In the F2k laboratory, 21st century physics and its phenomena are explored experimentally, introducing ideas that are the basis of current physics research at

the University of Helsinki. The F2k laboratory serves physics teachers and those interested in physics. In addition to pre-service and in-service teacher education, science and technology camps and clubs for children and youth are organized in the science lab, including workshops that deal with different phenomena in physics and teaching sessions for upper secondary school students, who are interested in physics. In F2k, a visitor can replicate Millikan's oil-drop experiment, explore the photoelectric effect, measure and model blackbody radiation, observe the spectra of different sources of light and determine the charge-mass ratio of the electron. At the same time, it is being explored how the phenomena in inquiry-based work can be connected to current research and applications, for example in astronomy, production of energy and climate change. During a visit, it is possible to have a look at the research laboratories on campus, to get to know the researchers and to get to know research that is conducted there.

Figure 15. The LUMA lab, called F2k teaching laboratory, carries out innovative science education in physics. The lab inspires children and youth as well as future teachers and teachers teaching on different school levels into meaningful teaching and learning of physics. F2k is significant in promoting science education of physics in Finland. In the lab, it is possible to explore new inquiry-based solutions and pedagogical innovations of science education in physics. In the above picture, future teachers are studying concepts and phenomena of physics through inquiry at the science lab.

4.4 Geopiste – Science Education in Geography and Geosciences

The LUMA lab, Geopiste, was established in 2010. Its purpose is to encourage children and youth into geography and geosciences with the help of new solutions and pedagogical innovations, and it aims at supporting teachers of geography in reaching the goals. Operation forms include active school group visits to the LUMA lab, science camps, science clubs and teachers' in-service training as well as producing material to be put online. Geopiste cooperates closely with geography teacher education and its newest research.

Figure 16. The LUMA lab, Geopiste, is the only lab at university in Finland that itself specializes in science education on geography and geosciences. In the picture, children participating in a science camp are performing field investigation with Geopiste in the Summer of 2017. The tools include: anemometers, thermometers, noise level meters and equipment for taking samples of the soil. (Picture: Inka Voutilainen)

Geopiste arranges visits for school groups, in which students get to hear about studying geography and about most recent research information, and participate in a variety of different kinds of activities. During these visits, it is possible to integrate e.g. field work with GIS-work (Geographical Information Systems) that is done on the computer. Students who work as instructors get experience from instructing visiting groups and a possibility to collect data for their thesis. A number of theses and new material has been carried out based on operations of Geopiste.[50]

Geopiste offers material online that has been developed for teachers to use, and equipment that can be borrowed. It has been in an active role in creating new materials for example making online exercises for the matriculation examination (the matriculation examination in geography has been one of the first subjects to be completed electronically since 2016). Geopiste has produced material with which

50 https://www.helsinki.fi/fi/tiedekasvatus/tutkimus/opinnaytetoita

teachers have had the chance to practice and teach new question types to the students that are connected to electronic exams. Geopiste supports the implementation of school curriculum also by borrowing different kinds of tools and material. These include e.g. GPS devices and different measuring equipment.

Geopiste has been organizing teachers' in-service training both in the forms of contact teaching as well as online. The focus area of the trainings has been to train teachers on electronic methods that belong under the term "geomedia" that has been used in curriculum for geography.

Geopiste produces new solutions and pedagogical innovations for science education in geography and geosciences, on the basis of recent research information. Its development areas in the future include exploiting communally produced geographic data and information in teaching (e.g. using Open Street Map charting as a part of geography education or doing research projects that use the visiting class' mutually collected mobile geographic data and information) and operating models in order to carry out a communal "influencing project" in the immediate surroundings of the school. Geopiste develops the possibility of using remote sensing data, acquired from drones with cameras, in the school facilities.

Geopiste perfoms broad national and even more international cooperation. It cooperates with the Ministry of Education and Culture's Aake project that develops the training of geography teachers (professional growth of a subject teacher and development of knowledge of subject didactics on the field of natural sciences) and with Sitra's "Teaching of circular economy to all school levels" -project (subproject of Tilapioneerit). In in-service training, cooperation has been carried out with BMOL, the organization for biology and geography teachers. A map drawing competition for children and youth is organized biannually in cooperation with the Cartographic Society of Finland. It cooperates with the Admission Services of the university in recruiting the instructors that organize visits. The operations of Geopiste are developed, based on research and according to the alignments of the Science Education Centre.

4.5 ChemistryLab Gadolin – Science Education in Chemistry

The oldest LUMA lab, ChemistryLab Gadolin was opened in 2008 in the Department of Chemistry at the Kumpula science campus. It is a modern learning environment, where new solutions and pedagogical innovations for teaching chemistry and applied chemistry are developed and implemented from early childhood education to university level education. Its main purposes are to inspire children and youth towards studying chemistry and its field, and to increase hobby-ism of chemistry through the use of new and encouraging inquiry-based experiments, computer modelling and meetings with specialists.

ChemistryLab Gadolin is a popular and authentic environment for studying chemistry. All in all, over 50 000 children and youths have visited the lab over the past ten years. Through active study visits, in total 33 000 students and teachers have explored new solutions and pedagogical innovations. Yearly, around 200 visits are organized, which means that there are around 4000 visitors per year. In addition, many other events are also organized in the ChemistryLab Gadolin. In 2017, 23 children celebrated their birthdays in the LUMA lab and according to the feedback, we were able to create joy of learning chemistry for all. Gadolin is also a popular place for international visits. In 2017, there were visitors from Australia, China, Singapore, Slovenia, South Korea and the United States.

The main operations form is instructed study visits, during which different level groups, from kindergartens to the university level, have a possibility to get to know new solutions and pedagogical innovations themselves. During a visit, it is possible to perform inquiry-based chemistry in an authentic university laboratory and to get to know the possibilities of molecular modelling in computer classrooms.[51] The visiting groups are instructed by future teachers, who have been trained for the job. In addition, visitors have the opportunity to meet researchers and have a look at their research laboratories and to get more information on topics in chemistry and what it is like to study chemistry at the university. There are also plenty of science clubs that are organized in the ChemistryLab Gadolin (e.g. a interdisciplinary Chemistry and art -club, see chapter 6), science parties, science camps and teacher training. Teachers can also borrow equipment and toolboxes for teaching purposes. For example, the water analysis briefcase is a popular thing to be borrowed. The ChemistryLab Gadolin's visiting calendar and teaching resources can be found on the website.[52]

51 Aksela, M., & Pernaa, J. (2009). *Arkipäivän kemia, kokeellisuus ja työturvallisuus kemian opetuksessa perusopetuksesta korkeakouluihin: IV Valtakunnalliset kemian opetuksen päivät*. Helsinki: Kemian opetuksen keskus, s. 40–49.

52 http://www.helsinki.fi/en/science-education/for-teachers/group-visits-to-science-labs/chemistrylab-gadolin

Figure 17. ChemistryLab Gadolin is Finland's oldest LUMA lab that operates at the university and is a popular place for national and international visits. It was established in 2008 in cooperation with the private sector. Gadolin received a **Global Best Award** recognition in 2014. One of Gadolin's focus areas for research and development is sustainable development in teaching, including the use of new forms of energy and materials in the teaching of chemistry. Pictured is the hydrogen car activity[53] that has been developed to inspire children learning chemistry. It is applied to many learning environments (Picture: Sofie Jokinen)

A modern science lab acts as a research environment for the learning and teaching of chemistry. Dozens of theses and publications[54] have already been written concerning the operations of Gadolin, and there is plenty of ongoing research being performed as well. Gadolin cooperates closely with the Unit of Chemistry Teacher Education's pre-service teacher education (a part of the new *Degree Program for Subject Teachers in Mathematics, Physics and Chemistry*) and with in-service training of chemistry teachers. Since the beginning of their studies, students in the program get to know chemistry by teaching children, getting to know teachers and other specialists, and to collaborate with different partners. A variety of methods have been documented to inspire students to become chemistry teachers, increase their skills in chemistry and augment different pedagogical skills[55].

At the ChemistryLab Gadolin, cooperation with the researchers at the university and the private sector (e.g. chemical industry) is active. Collaborative design-based

53 Aksela, M., & Boström, M. (2012). Supporting Students' Interest through Inquiry-Based Learning in the Context of Fuel Cells. *Mevlana International Journal of Education*, 2, 3, s. 53–61.

54 Theses and activities: https://www.helsinki.fi/fi/tiedekasvatus/tutkimus/opinnaytetoita

55 Aksela, M. (2017) ChemistryLab Gadolin as a Relevant Learning Environment for Lifelong Learning. ESERA2017. http://keynote.conference-services.net/resources/444/5233/pdf/ESERA2017_0751_paper.pdf

research (see chapter 2.2) has been carried out with companies and significant inquiry-based work that inspires youth has been developed. An example of this is a doctoral dissertation, "*Meaningful design-based research of a non-formal learning environment of chemistry in cooperation with the working life"* (2017)[56].

The broad operations are enabled by the university, and support and resources given from the cooperation partners. Gadolin's important cooperation partners in the private sector, are Neste Oyj (the main sponsor), Chemical Industry Federation of Finland, Aga Oy, Borealis Polymers Oy, Kemira Oyj, UPM Oyj, BASF Oy, Bruker Corporation, VWR International Oy, Laskentaväline Oy, Finnish Chemical Magazine, Kemia; 3M Finland Oy, Milliot Science Oy, Metrohm Nordic Oy, Is-Vet Oy and Thermo Fischer Scientific Oy. In addition, there are also important representatives from the Finnish National Agency for Education, representatives from different school levels (also from vocational schools) and representatives of organizations. Gadolin has also collaborated with the Faculty of Pharmacy in researching and developing new inquiry-based work, mainly in the form of thesis.

A steering group, which consists of representatives from different cooperation partners, supports the ChemistryLab Gadolin. We look forward to working with new cooperation partners.

4.6 Linkki – Science Education in Computer Science

Science Lab Linkki was opened in 2011 at the Department of Computer Science at Kumpula campus. It produces new solutions and pedagogical innovations for science education in computer science. The following describes Linkki through its establishment, its aims and innovative examples of its diverse operations.

56 Ikävalko, V.-M. (2017). Mielekkään kemian non-formaalin oppimisympäristön kehittämistutkimus yhteistyössä työelämän kanssa. Helsinki: Helsingin yliopisto. http://urn.fi/URN:ISBN:978-951-51-3165-2

Figure 18. Linkki is one of Finland's leading operators specializing in science education in computer science. One of the aims of Linkki's diverse science education program is developing interest in programming in girls. Pictured above are some participants in Linkki's Create Your Own Virtual Pet –summer camp. (Picture: Arto Wikla)

Linkki cooperates closely with the researchers and specialists at the Department of Computer Science. The first events in 2011 were camps and clubs organized for children and youth, where basic programming skills were learned through game programming. An active participant in establishing the activities was the RAGE research group (Agile Education Research). The group focused on developing agile teaching methods for improving interaction between students and teachers. Their widely adopted Extreme Apprenticeship model[57] [58] is one of the key operation modes in Linkki, too. RAGE's MOOC programming course contributions are an essential resource to Linkki's operations[59] in alleviating the lack of materials for teaching programming skills[60] in schools. The Department of Computer Science has utilized these basic programming MOOCs both for educating university students, but also

57 Vihavainen, A., & Luukkainen, M. (2013). Results From a Three-Year Transition to the Extreme Apprenticeship Method. In *Proceedings of the The 13th IEEE International Conference on Advanced Learning Technologies ICALT*.

58 Vihavainen, A., Luukkainen, M., & Kurhila, J. (2013). MOOC as semester-long entrance exam. *Proceedings of the 14th annual ACM SIGITE conference on Information technology education*. New York: ACM, 177–182

59 Aarnio, H. (2017). Linkki-resurssikeskuksesta ensiapua ohjelmoinnin opetukseen, *Dimensio, 81*(1), s. 7–11.

60 Kurhila, J., & Vihavainen, A. (2015). Purposeful MOOC to Alleviate Insufficient CS Education in Finnish Schools. *ACM Transactions on Computing Education*. 15, (2), s. 10:1–10:18.

in cooperation with secondary schools, where students can complete the course while still in upper secondary school. They are also an important tool in teachers' in-service training. Through MOOC courses, it is also possible to receive a study place at the University of Helsinki Department of Computer Science. More information on MOOC courses can be found in chapter 5.

Linkki develops new solutions and pedagogical innovations in order to increase general understanding of computer sciences, and programming especially, for everyone. Gaining basic skills in programming is a good way to adopt information and skills which are needed in the current technology filled life in our modern digitalized society. Due to this need of developing general understanding, Linkki chose "**Programming for everyone**" to label its project in the national LUMA FINLAND development program, aiming to support instructing people of all ages, from primary school level to seniors. Since 2016, the curriculum for Finnish primary and lower secondary schools has contained rough learning goals for programming and use of technology, not as a separate subject, but integrated in mathematics and other subjects such as crafts, languages and geography. In order to prepare for support in the change, Linkki broadened its aims to include teachers, teacher training and in-service training.

Linkki promotes the possibilities brought by digitalization by collaborating with the Finnish National Agency for Education and with schools. As programming, technology and digital education in schools is going to be further developed in the future, it is crucial that schools and LUMA operators collaborate when developing computer sciences associated learning goals for schools. Together we need to find a way to match learning goals in schools with the skills expected of students entering university in computer sciences, information systems and data sciences, as well as associated fields and fields applying methods from these subjects. Cooperation with education networks involves direct collaboration in schools, taking part in the organizing and planning of in-service training with offices such as the City of Helsinki's Education Division and Regional State Administrative Agencies.

As a learning environment, Linkki offers programming clubs, programming camps and camps with interdisciplinary themes to children and youth – and in some cases also to parents and grandparents. Activities are offered for different skill levels in different programming environments: beginners use graphical, visual environments, while those who already have a grasp of the basics progress to text-based environments. Typically the working methods are activity or challenge based, involving for example game development. More information on the forms of club activities can be found in chapter 6.2. Other ways of reaching young people include taking part in programming events, such as jams and hackathons, and facilitating programming clubs in schools.

Linkki produces educational models and teaching materials that support the teaching and learning of programming. The materials are freely available for teachers

- an open material bank is available on the LUMA FINLAND development program's "Programming for everyone" project's website. The club activities of Linkki make it possible to research the functioning of these educational models, while simultaneously training student teachers to act as programming instructors. The aim is not necessarily in producing professional programmers in schools, but rather in helping young people become proficient operators of modern technologies, with an understanding of the underlying concepts in these technologies. Therefore, the teaching models and materials developed exploit phenomenon-based learning and formative assessment in exploring key concepts. It is essential that interdisciplinary collaborations be integrated into teaching at all levels. More information about different models of educational collaboration can be found in chapter 5.2.

Research guides Linkki's operations, as teaching models and learning materials are always based on research. Underlying themes include the effects of gamification and story-telling based learning, methods of increasing students' awareness of gaining new skills, effects of various pedagogical models, and using software engineering methods as part of the pedagogical approach [61] [62] [63] [64]. Through research, we also wish to understand how the skills of different generations of students improve as the national curricula becomes more detailed and more widely adopted. Other important areas include discovering and mitigating demographical obstacles to entering the field, and understanding how pedagogical techniques can act as an equality improving asset. Equality is one of the big challenges in the male dominated field of computer science. In addition to issues with gender balance, this field that was previously quite open to visually impaired people is fast becoming less so, and home background plays a significant role in the all-important early experiences of success in the field.

Linkki cooperates widely with different learning environments, municipal youth services, parent-teacher associations and the media. Specific projects include the Pulmaario project, where Linkki cooperated with libraries,[65] which has helped in raising demand for programming skills nationally. Also "Rosa's code", a game produced by YLE (the Finnish Broadcasting Company) in 2016, encouraged young

61 Aarne, O., Peltola, P., Leinonen, A., Leinonen, J., & Hellas, A. (2017). Adolescent and Adult Student Attitudes Towards Progress Visualizations. *ISSEP*.

62 Heinonen, K., Hirvikoski, K., Luukkainen, M., & Vihavainen, A. (2014). Using CodeBrowser to Seek Differences Between Novice Programmers. *SIGCSE '14 Proceedings of the 45th ACM technical symposium on Computer science education* . New York: ACM, s. 229–234.

63 Vikberg, T., Vihavainen, A., Luukkainen, M., & Kurhila, J. (2013). Early Start in Software Coaching. *Agile Processes in Software Engineering and Extreme Programming: 14th International Conference, XP 2013, Vienna, Austria, June 3–7, 2013, Proceedings: 14th International Conference, XP 2013, Vienna, Austria, June 3–7, 2013. Proceedings*. Baumeister, B. & Weber, B. (toim.). Heidelberg: Springer-Verlag, s. 16–30.

64 Longi, K. (2016). *Exploring factors that affect performance on introductory programming courses*. Pro gradu. Helsinki: Helsingin yliopisto.

65 Räsänen, J. J., Sumu, V., Tuominen, J. E., Kaukoniemi, H., & Terrihauta, P. (2016). *Pulmaario – matematiikkaa ja ohjelmointia: ohjaajan opas*. Helsinki: Helsingin kaupunginkirjasto.

people to explore the digital world by completing programming tasks along with physical tasks in museums and libraries, in order to experience the interactive story of the project. The programming challenges devised by Linkki were solved 10 000 times. Collaborations with Helsinki City youth services include camps and game jam events, which have been an essential tool in reaching youths from different backgrounds. In specific schools Linkki has also collaborated with parent associations to organize programming clubs with varying themes, such as cultural or environmental aspects.

Linkki further develops its international collaborations in the near future. International connections in the development of teaching were advanced, for example, by the ISSEP-conference[66] [67] in 2017 (International Conference on Informatics in Schools: Situation, Evolution and Perspectives), organized at the Department of Computer Science. The conference themes included teaching of computing and algorithmic thinking for students in primary and secondary schools.

Linkki is a much sought-after location for national and international visits. These visits support the development of new solutions and pedagogical innovations in computer science education. During the years 2015–2017, more than 50 school groups and more than 100 teachers have visited the lab, and dozens of school groups with their teachers have taken part in programming workshops during different events. Yearly, around 500 children and youths take part in clubs and camps, and through different events we have been able to reach thousands more. Linkki's in-service training events, online courses and open online classes reach hundreds of teachers every year. Due to its nature, the programming-MOOC has reached the largest audience: the amount of completed assignments reached over a million already in 2014.

4.7 Math Lab Summamutikka – Science Education in Mathematics and Statistics

The Math Lab (LUMA lab) was opened in 2011 on the Department of Mathematics and Statistics at the Kumpula campus. At the beginning, the lab was called: Math Lab Origo, because it is located physically in the center of the building. Therefore, it offers a meeting place for university and school mathematics, development of teaching, hands-on math and recent research. At the beginning of 2017, the name of the lab was changed into Math Lab Summamutikka.

66 http://issep2017.cs.helsinki.fi/

67 http://www.springer.com/us/book/9783319714820

Figure 19. Math Lab Summamutikka as one of LUMA labs is Finland's only lab that operates at the university and that specializes in science education in mathematics. This is a place, where memorable moments are made, e.g. in science camps, among new solutions and pedagogical innovations and their development. Various researches and theses have been made on the topic of science education in mathematics, for example the innovative Pulmaario project (see chapter 6 for more information). In the picture, the participants of the camp have a question to be answered: What kinds of skyscrapers would implement the condition of the exercise? (Picture: Anni Jyrinsalo, Anne Kivistö and Noora Nuutinen)

New solutions and pedagogical innovations are produced for the science education of mathematics at Summamutikka. Its purpose is to support and promote the teaching and learning of math, and the hobbyism of math for all. The main concept is that everyone could feel that they are good in math and to offer positive experiences with math. The aim is also to show that mathematics can be and is a lot of fun. In the future, new activities and pedagogical innovations are aimed at being developed at the math lab, e.g. on the areas of: applications in math and statistics, and on the other hand the interaction between math and arts. Summamutikka is in close cooperation with the new *Degree Program for Subject Teachers in Mathematics, Physics and Chemistry* and in its research. Various theses are made from themes connected to the math lab[68].

The activities organized at the math lab are versatile and they include school visits, club meetings, summer camps, teacher training and math birthdays. The

68 You can find several thesis here: https://www.helsinki.fi/fi/tiedekasvatus/tutkimus/opinnaytetoita.

Summamutikka activities are such that explore mathematics in an active way, through e.g. play, games, doing arts and brain teasers. Along the years, mathematical activities and brain teasers have been collected in a material bank of the Math Lab Summamutikka[69], there they are available for students, teachers and anyone interested in math, to use freely.

Summamutikka cooperates closely with math teacher education and the development of teaching, and the research and teaching operations in math and statistics at the university[70 71 72 73 74]. Cooperation has also occurred with other partners. In 2014, Summamutikka began to cooperate with Tevella Oy, this includes testing Tevella's equipment and then reporting and giving feedback on the tested items.

In-service training sessions and other events aimed at teachers, have been organized in cooperation with the Varga-Neményi organization as well as with Matikkamaa in Espoo and Helsinki. Activities for children and youth, such as clubs and competitions, have been organized together with the Helmet network in the Helsinki Metropolitan Area, Statistics Finland and with the training unit of the Finnish Mathematical Society. In addition, Summamutikka has participated in organizing various events, for example the "Night of Mathematics" event that was organized two times during 2012–13 in cooperation with the Science Centre Heureka.

The Math Lab Summamutikka offers versatile activities that are popular. During 2011–17, over 200 university visits have been organized in Summamutikka. In total 5000 children and youth from early childhood education to the secondary level have visited. The popularity of the visits has increased with every year and in 2017, 53 school groups, meaning 1326 students visited the math lab. In addition to the university visits, thousands of children and youth have been taking part in Summamutikka in the forms of clubs, camps and Math Days. For example in 2017, Summamutikka visited different schools in order to organize clubs and Mathematical Days. Around 2000 children and youth participated in these events. Summamutikka is also popular for both international and national visits (see Picture 1 in the Foreword section).

69 http://blogs.helsinki.fi/summamutikka/

70 Karjalainen, E. (2017). Kehittämistutkimus: Virtuaalinen matematiikkakerho. https://helda.helsinki.fi/handle/10138/224587

71 Ristiluoma, M. (2017). *Murtolukujen opetus toiminnallisesti – opetuskokeilu peltipizzamallilla*.

72 Räsänen, J., Sumu, V., Tuominen, J., Kaukoniemi, H., & Terrihauta, P. (2016). Pulmaario – matematiikkaa ja ohjelmointia: Ohjaajan opas. Helsinki: Helsingin kaupunginkirjasto. http://pulmaario.luma.fi/

73 Saarinen, P., & Simonsson, M. (2012). *Toiminnallisen matematiikan reseptivihko*. Helsinki: Unigrafia.

74 Björklund, J., Lehto, S., Pasanen, S., & Viljanen, M. (2002). *Sukkia ja muuta matematiikkaa*. Helsinki: MFKA-Kustannus Oy.

5. NEW APPROACHES OF SCIENCE EDUCATION FROM EARLY CHILDHOOD EDUCATION TO UNIVERSITIES

This chapter looks at what kinds of approaches science education operations of the Centre have brought into teaching from early childhood education to the university level through diverse cooperation, here especially into teaching at the University of Helsinki. The operations enable the possibility for future researchers and specialists to learn for example while instructing functional visits or science adventures or then through exercises for practicing ("learning while teaching"), to develop skills in interaction and to inspire children and youth towards science (act as ambassadors of science). It is possible that the future scientists get new ideas and viewpoints into their research in interaction through children and youths' questions, and a possibility to carry out popularization of their own research.

The Science Education Centre offers new opportunities for pre-service teacher education cooperation with different level teachers and cooperation partners, carrying out current research and spreading it out and to be able to develop through interaction, and to implement teachers' in-service training in new ways, for example virtually. New models are developed in the operations and in these models, student teachers that are completing their basic training and teachers in school, study together or they study together with students (in upper secondary school), researchers or other specialists in the private sector (e.g. industry). At the same time, they are able to learn in good interaction.

5.1 General

Science education of the Centre is a part of teaching at the university and its development. Here, new ways of implementation both for teacher education and for teaching at the university are developed (see chapter 5.2.5). The Science Education Centre strengthens teacher education that is based on research and integrated in science education, in the entire University of Helsinki, from early childhood education to the secondary level. The Centre promotes the connections of basic teacher training (pre-service education) in the working life and the surrounding society.

In science education, new connections are constructed between different fields of science and subjects and phenomena, concepts and things are being looked at from the viewpoints of various subjects. This is done in a broader way and according to

the new core curricula for basic education and secondary education, according to integrative teaching and based on phenomena. Along the years, versatile operations concepts of science education that have been observed to function properly, have been developed and integrated in teacher education. The Centre has an important purpose in spreading these concepts slowly around all the different fields of science at the university.

In a number of courses for pre-service teacher education in different faculties at the University of Helsinki, non-formal (target-oriented) science education is a part of meaningful teacher education (see new courses in chapter 5.2.4). Different forms of science education (see figure 20 in more detail) inspire towards important teaching in different levels and lifelong learning as well as cooperation with different partners in future work. Especially their significance before the vital part of pre-service teacher education, teaching practice, has been observed as an inspiring experience. It strengthens teachers' orientation and identity in studies and work.

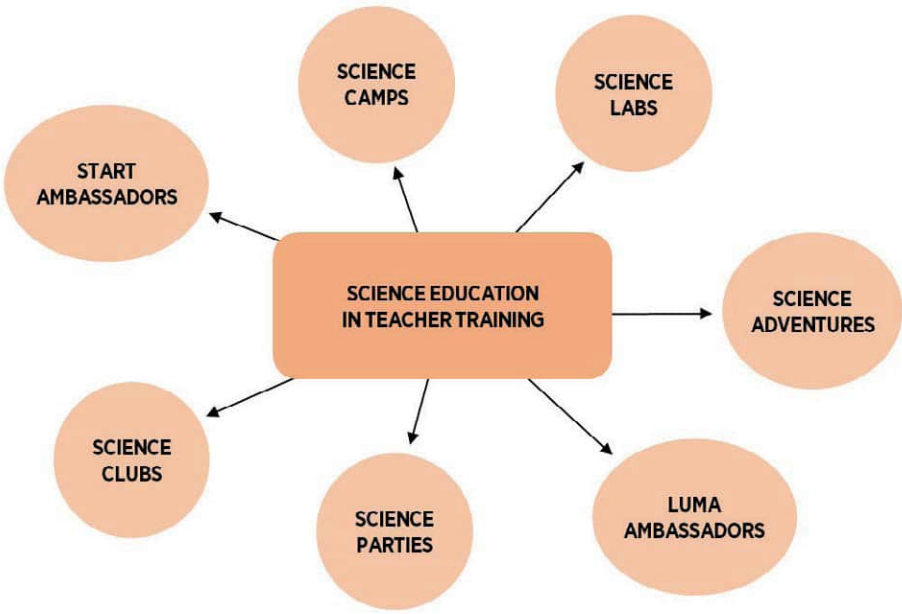

Figure 20. The activities of the Science Education Centre offer excellent possibilities for all students in every faculty at the University of Helsinki in gaining inspiring experience from non-formal teaching in different fields of science. The learning environments of the Science Education Centre create new possibilities in inspiring learning already during basic teacher training. As a part of their education, students training to be teachers learn together with children, youth and the entire families while they instruct science education activities and when they reflect on theory by completing various exercises. A virtual online science education course (MOOC course, see chapter 5.4.2) gives good, theoretical and practical advice for their implementation.

In many faculties there are courses such as "Orientation in teaching" for students, where the different forms of science education are present (see figure 20) and they cooperate with different cooperation partners (see the following chapters for more information). For example, **Me, a Teacher? orientation course** has been organized for everyone, who have thought of becoming teachers. It has been organized **for the students at the Faculty of Arts** for a couple of years. In this course, students of languages, literature, history, philosophy and religious science, have explored teacher's professional identity and the variety of work tasks by visiting a school, listening to lectures of visitors from different fields, doing projects in small groups and by interviewing a teacher. In the spring of 2018, "Me, a Teacher?" course is going to be organized for the first time in cooperation with Me & My City. The students get to go to the facilities of Me & My City and to instruct 6th graders, which gives them experience in interaction situations and in instruction in a non-formal learning environment.

There is also a course on "Orientation into teaching" in **the subject teacher training of mathematics, physics and chemistry**, which has offered non-formal activities since 2004. It has had activities such as acting as an instructor in Ksenonit science day for families (later known as Jippo science day for families) or instructing an event in school, visiting a school and carrying out a small case study as a part of theory taught in the course. See the following chapters for more information on other methods.

The **in-service training operations** of the Science Education Centre have been versatile since the beginning of the operations. The role of the university here is to spread newest research information and new solutions as well as pedagogical innovations to the teachers, in different forms. The training promotes teachers' lifelong learning and interaction with the University of Helsinki and different cooperation partners. The Centre promotes, coordinates and implements research that supports teacher training and increases teachers' expertise. For example, in science education at the Faculty of Arts, various inspiring courses for in-service training have been organized[75,76]. The Centre also informs about events, phenomena and research connected to teachers and teaching. In a strong interaction, both parties learn and their science competences are increased.

Popular, **international in-service training** has been carried out and is going to be carried out even more in the near future with cooperation partners both in Finland as well as abroad. For example, we have collaborated with China who has organized both in-service training sessions and lectures for teachers and instructors of teacher training.

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75 Huhtala, A. & Vesalainen, M. (2017). Challenges in developing in-service teacher training: Lessons learnt from two projects for teachers of Swedish in Finland. *Apples – Journal of Applied Language Studies*: Special issue on CoDesigns: Envisioning multi-sited language education policies. 11 (3), 55–79

76 Huhtala, A. & Vesalainen, M. (2017) Avaimia onnistuneeseen kieltenopettajien täydennyskoulutukseen. *Ammattikasvatuksen aikakauskirja*. 19, 4/2017, 62–69

Figure 21. Teachers' in-service training has been carried out during the previous years in China with different cooperation partners. (Picture: Jing Ping Xia)

The Science Education Centre at the University of Helsinki participates actively in **developing national teacher education**, and is also in diverse interaction with teachers. During previous years, it has been a part of the national Teacher Education Forum[77] as well as a part of national LUMA forum for teacher educators of LUMA subjects[78]. It has also been participating in organizing the national LUMA Days for teachers and national LUMA Week for all since 2004. In addition, a number of Days for specific fields of science have been organized, for example a couple of Math Teaching Days and about 10 Chemistry Teaching Days,[79] in which education in universities has been a topic. The purpose of the operations of science education at the University of Helsinki is to be able to work in close interaction with teachers, especially the teacher alumni at the University of Helsinki, and to learn in interaction.

77 http://minedu.fi/opettajankoulutusfoorumi

78 http://www.luma.fi/keskus/kansallinen-luma-aineiden-opettajankoulutuksen-foorumi/

79 https://www.helsinki.fi/fi/tiedekasvatus/kemian-opetuksen-paivien-kirjatverkkojulkaisut

Figure 22. The national **LUMA Days** that are organized once a year in different universities, offer a good learning and meeting forum both nationally and internationally for teachers, teacher educators, researchers, future teachers and cooperation partners. In these forums it is possible to spread new solutions and pedagogical innovations and to start new openings based on recent research information and a demand. Several LUMA Days have been organized at the University of Helsinki since 2004. At the same time there is also an International LUMAT Symposium taking place. Yearly, tens of teachers and researchers from different countries participate in the LUMA Days and the LUMAT Symposium.

5.2 New Models for Collaborative Learning in the University Level

New models for collaborative education for teaching in the university level are developed in science education of the Centre. For example, ***Science adventures*** (that are also known as learning adventures) is an inspiring operating model both for future teachers and students at the university. Non-formal learning environments – LUMA labs, clubs and camps – open new possibilities in meaningful studying at the university level.

Figure 23. A mutually organized **This works!** event has been an example of how different operators (future teachers, teachers working in the field, teacher training instructors at the university and specialists in the private sector) have the possibility of learning together and to share joy of learning (Picture: University of Helsinki Science Education Centre)

5.2.1 Science Adventures – Inspiring Learning Outside the University

Science adventures (that are also known as learning adventures) have been organized for quite a while both in subject teacher education of Mathematics and in the Faculty of Arts. In the following part, both models are being described. In the future, the Science Education Centre organizes science adventures in a interdisciplinary way on the themes of the thematic focus areas of science education and in aligned ways of complementation in cooperation with basic teacher education (pre-service education) (see chapter 1.3).

In teacher education in the Faculty of Arts, learning events for primary school students that are called "learning adventures" have been organized for a long time. The adventures that have been designed and organized by subject teacher students, have inspired children about humanities and taught skills needed in thinking and conceptualization. This supports students that organize them, to grow into teachers: they get practical experience of interdisciplinary things and of instructing pupils in non-formal learning environments. While organizing these adventures, students have developed their interaction skills in a interdisciplinary collaboration and they have received practical experience of designing activities and instructing children. Organizing learning adventures in the form of a course has supported the growing of students into teachers.

Figure 24. Science adventures in schools are an inspiring way to carry out teacher education. The instructors of the learning adventure – the future teachers in humanities, can be seen in the picture. (Picture: Mika Federley)

In the learning adventure model, a school class is divided into smaller groups, in which children go around from station to station and complete assignments that are connected to a theme or a story, and while they are doing this, they learn new things. Each learning adventure has a specific theme: for example, on the 375th Anniversary of the University of Helsinki in 2015, an adventure was organized with a theme "a new world view". In this adventure, 4th to 6th graders solved a mystery called the Agent 375, following the principles of gamification and interdisciplinarity. The subject teacher students described the execution of the learning adventure in a blog[80].

Mathematical science adventures, the so called **Math Days** are organized in school facilities as a part of a school day. University students, who usually study to be teachers in math, instruct these Math Days. This has been a part of math teacher education at the University of Helsinki for a long time. Students have designed and

80 http://blogs.helsinki.fi/uma-oppimisseikkailu/2015/03/02/etusivu/

carried out these Days as part of their studies, e.g. as a part of courses for students studying on the teacher line or part of work practice.

In the model for Math Days, two university students prepare a workshop for different school levels. Different school groups can visit the workshop during the day. Hands-on activities are performed in the math workshop, and the theme for the workshop can be a theme picked up from the curriculum or then a theme that is not included in the school curriculum.

Figure 25. Hands-on, creativity and independent work are important in **Math Days**. The students get more experience from teaching and working with children. For some students, this event is their first experience of working with children. At the same time students get to know hands-on mathematics and get new ideas for their work as future teachers. (Picture: University of Helsinki Science Education Centre)

Math Days are also testing places for testing ideas developed in theses. Many people writing their theses have tested the activities, games and other learning entities that they have themselves developed, in the Math Days[81]. During the day, several student groups visit the workshop and it is possible to ask them to evaluate the activity and to give ideas for improving the activity.

5.2.2 LUMA Labs as Learning Environments in University Level Teaching

LUMA labs (see chapter 4 for further information) are inspiring learning environments and they are a part of **teachers' pre-service education and/or in-service training for teachers teaching on different levels**. Often future researchers and specialists also participate in the LUMA labs. Different learning assignments in pre-service teacher education and in its research, are connected to science labs.

81 https://www.helsinki.fi/fi/tiedekasvatus/tutkimus/opinnaytetoita.

For example, the LUMA lab, **ChemistryLab Gadolin**, has been operating as a studying environment in chemistry teacher education since 2008 (currently also in the new *Degree Program for Subject Teachers in Mathematics, Physics and Chemistry*) at the Department of Chemistry, on Kumpula campus, at the University of Helsinki. [82] [83] [84] [85] [86] In many courses on chemistry education, different tasks are designed and carried out as a part of learning visits to the ChemistryLab Gadolin. These tasks as well as programs for all the visits, are designed based on the aims of the course and on the requirements/wishes of the teachers of visiting school groups. The assignments can be for example **reflection assignments** (e.g. observing some topic connected to a theory and pondering on its viewpoints in practice), **research assignments** (e.g. completing a small case study from the point of view of a theory), **assisting exercises** (e.g. making solutions needed in inquiry and helping out in preparing modern technology) and **instruction assignments** (e.g. instructing an entire study visit or a part of it).

By instructing visiting children and youth in the Gadolin and by having discussions with the teachers of teaching groups, a future teacher learns chemistry, many kinds of skills and receives inspiration for studying to become a teacher and inspiration for the future profession. For the visiting teacher, the visit acts kind of like **a new model for in-service training**: the teacher gets to observe and reflect children and youths' learning through new and innovative activities that the future teachers instruct, and the teacher has the chance to have discussions with the future teachers.

A good example of collaborative learning is the course "Inquiry in chemistry and its integration to other sciences" that aims at supporting and interesting future teachers and in-service chemistry teachers that already work in the field, on carrying out inquiry in school in a meaningful way. The themes during the course have been e.g. electrochemistry, colorimetry, sustainable chemistry, delicious chemistry and beautiful chemistry. Student teachers and teachers working in the field (kindergarten

82 Aksela, M. K. (2010). Evidence-based teacher education: becoming a lifelong research-oriented chemistry teacher? Chemistry Education Research and Practice, 11(2), 84–91. DOI: 10.1039/C005350N

83 Aksela, M. K. (2016). Foreword in a special number "Promoting innovative and collaborative chemistry education through evidence-based chemistry teacher education". *LUMAT-B: International journal of math, science and technology education* , *1*(3).

84 Aksela, M. K., & Ikävalko, V-M. K. (2016). How to promote relevant practical work in science education through a non-formal learning environment? Teoksessa I. Eilks, S. Markic, & B. Ralle (Toimittajat), *Science Education Research and Practical Work : A collection of invited papers inspired by the 23rd Symposium on Chemistry and Science Education held at the TU Dortmund University, May 26–28, 2016* Aachen: Shaker.

85 Aksela, M. K., Vartiainen, J. L., Tuomisto, M., Turkka, J. S., Pernaa, J. I. S., & Tolppanen, S. (2016). Promoting Meaningful Science Teaching and Learning Through ICT in the Finnish LUMA Ecosystem. Teoksessa H. Niemi, & J. Jia (Toimittajat), New Ways to Teach and Learn in China and Finland : Crossing Boundaries with Technology Frankfurt am Main: Peter Lang. DOI: 10.3726/978-3-631-69873-0

86 Affeldt, F., Tolppanen, S., Aksela, M. K., & Eilks, I. (2017). The potential of the non-formal educational sector for supporting chemistry learning and sustainability education for all students – a joint perspective from two cases in Finland and Germany. *Chemistry Education Research and Practice*.

teachers, class teachers and subject teachers) can plan and carry out new inquiry-based work and learn from one another. You can find other collaborative courses of chemistry teacher education on the study programme's website.[87]

In the Linkki science lab (LUMA lab), teachers and students learn new things by working together: school visits – from schools or to schools – give teachers and schools the possibility to experience programming and core computer science concepts with their students and other teachers in a way that suits the age of the students. In programming and computer sciences teacher training we target teachers of specific subjects along with primary school teachers and preschool personnel.

5.2.3 Science Clubs and Camps as Learning Environments

The non-formal learning environments of science education (such as science clubs and camps) bring new possibilities in inspiring university studying, especially during pre-service teacher education. Science clubs as a part of teacher education as tested for the first time in 1998 as a part of future elementary teachers' education in natural sciences at the University of Helsinki[88]. The received positive experience encouraged in increasing the amount of science clubs as learning environments in teacher education. Future teachers were even more interested in sciences, because of the interested children in science clubs. Children acted as inspiring catalysts for future class teachers in this model.

Hundreds of science clubs and camps (see chapter 6 and 7 in more detail) have been organized in the science education operations since 2003, and at the same time they have acted as inspiring learning environments for future teachers. For example, in the summer of 2017, 31 science camps were organized for children and youth. Working as instructors, students learn together with children, youth, and entire families and by reflecting on theory with different kinds of exercises. At the same time, they receive work experience for their future work as teachers, and possibly experience for organizing a science club at their school.

The Science Education Centre has a long tradition of training future teachers in carrying out science clubs and camps (see chapter 5.4.1). A virtual course on science education (a MOOC course, see chapter 5.4.2) has been developed based on the good experience received from the above-mentioned education. It gives good and theoretical as well as practical advice on carrying out these science clubs and camps nationally and internationally.

87 https://www.helsinki.fi/fi/ohjelmat/kandi/matematiikan-fysiikan-ja-kemian-opettajan-kandi-ja-maisteriohjelma/opiskelu/opintosuunnat/kemian-opinnot

88 Aksela, M. & Mikkola, K. (1999) Kuinka luonnontieteitä voisi opettaa lapsille mukavalla ja motivoivalla tavalla?: Tiedekerhotoiminta innoittajana luokanopettajien peruskoulutuksessa. *Julkaisussa: Didacta Varia*. 4(2). 17–48

International science education as a part of teacher education will be strengthened in the near future. Good experience of an international learning environment has been achieved with an international science camp: Millennium Youth Camp (see chapter 7.3). Youth from over 30 countries participated on the camp and they were instructed by trained student teachers. At the same time, future teachers learned more about the topic, developed skills in teaching and interaction, and learned to encounter youth from different cultures.

5.2.4 New Courses in Cooperation

New courses have been developed in science education of the Centre together with different cooperation partners. For example, the course ***Global challenges*** describes the way of how to implement collaborative learning between future subject teachers and students on the upper secondary school. ***LumaLähetit*** *(LUMA ambassadors)* operations describes learning together with children, student teachers and school teachers. An example of the course ***Mathematics and natural sciences in society*** describes cooperation between future subject teachers, the private sector (e.g. industry) and schools, and also internationally. ***StarT ambassador operations*** as a part of a course *Science education* describes learning that occurs between school students, teachers and future teachers and with different cooperation partners in kindergartens, schools and clubs. The courses have been described below.

(i) The Course 'Global challenges' in Cooperation with Upper Secondary Schools

The aim of the course **'Global challenges'** is to offer upper secondary school students a possibility to learn about current global phenomena based on most recent research information and to explore university studies – a possible future study place. This creates a perfect possibility for teacher students to practice themes (that follow the new curriculum) on phenomenon-based teaching and project-based learning as a method. In this course, subject teacher students from different faculties design and carry out a phenomenon-based entity of project-based learning for upper secondary school students as part of their studies. Upper secondary school students carry out projects in small groups, dealing with themes that have to do with global challenges (these have then been designed by the university students). This includes themes such as sustainable future, challenges and possibilities of multiculturalism, the choices of an aware consumer as well as advertising and media literacy.

This course is a good example of close cooperation between the Finnish National Agency for Education and the university. It is also a good model for subject teacher

education that unites all the faculties, which supports cooperation between future teachers and team teaching in the implementation of phenomenon-based teaching in the future profession, according to the new school curriculum. The Science Education Centre at the University of Helsinki and the upper secondary education unit of the city of Espoo (the initiative for cooperation came from the city of Espoo) organized a course in spring 2017 together for the first time. Subject teacher students from four faculties took part in the course, most of them were from the Faculty of Arts and the Faculty of Science. The outcomes of the project were presented to teachers at the national LUMA Days in May 2017 through a PowerPoint presentation, videos and an Instagram account. The course 'Global challenges' is going to be carried out also in spring 2018, based on the positive experiences that were received from the first course. It supports phenomenon-based, interdisciplinary project-based learning in upper secondary schools, and supports the growing of university teachers into subject teachers.

The course is going to be integrated even more in the national StarT operating model (see chapter 3.2.2). This is also one of the development objects on behalf of the University of Helsinki in a development program (in 2018–19) for teacher education funded by the Ministry of Education and Culture. The course is developed based on the newest research, and research is conducted and theses are written about the course.

(ii) The Luma ambassadors operating model as a learning forum for future teachers

The innovative **Luma ambassadors** project[89] [90] [91] (a project of the earlier LumO resource centre) has several goals:

- to develop cooperation between the university and schools (areas of development: inquiry-based learning, interdisciplinary learning entities and team teaching)
- to develop the abilities and motivation of teachers and student teachers in carrying out different teaching entities that exploit various approaches, equipment and learning environments

89 https://tuhat.helsinki.fi/portal/fi/projects/lumalahetit-eheytta(68041442-c978-4c2c-92e7-b4bf2666f78a).html.

90 http://suomi.luma.fi/hankkeet/koulutuksesta-kouluun/

91 https://tuhat.helsinki.fi/portal/fi/projects/lumalahetit-eheytta(68041442-c978-4c2c-92e7-b4bf2666f78a).html

- to develop and produce new ideas and material for inquiry-based learning
- to increase abilities for cooperation between colleagues and team teaching and to form a network in teaching

Figure 26. The course Global challenges is a perfect example of collaborative learning and close cooperation between different partners. On the interdisciplinary Global challenges course in 2017, upper secondary school students – the persons of the future – visited the Helsinki Think Company with the subject teacher students (from 4 faculties) (Picture: Amanda Lehtola)

In the operating model, *Luma ambassador teams* are formed from a couple of teacher students and teachers and a mentor from the university. The purpose of the team is to create, develop and implement interdisciplinary teaching entities for schools. Themes have been for example *human and health*, the *microworld, inventions and outdoor fieldworks*. Most interdisciplinary themes have been developed in cooperation with teachers and teacher trainees. The operations are evaluated regularly. Inquiry-based teaching entities are developed based on evaluation and experience, new teaching entities are being developed. The teaching material produced in the *Luma ambassador* project has been published, and it

can be used freely in teaching. There is a lot of research and theses on the topic.[92]
93 94 95 96 97 98 99 100 101

Figure 27. Students conducting research in the instruction of a Luma ambassador. In good interaction, everyone is able to learn from one another. (Pictures: Anttoni Kervinen)

92 Kervinen, A., Uitto, A., Kaasinen, A., Portaankorva-Koivisto, P., Juuti, K. & Kesler, M. (2016). Developing a Collaborative Model in Teacher Education – An Overview of a Teacher Professional Development Project. *LUMAT: Research and Practice in Math, Science and Technology Education*, *4*(2), 67–86.

93 Uitto, A. ja Nordström, T. (2017). Inquiry approach in the outdoor learning environment. Submission to *ESERA 2017 Conference E-book*.

94 Lemmetty, T. (2017*). Biologiaa tiedeleireillä: leiriaktiviteettien kiinnostavuus lasten näkökulmasta*. Pro gradu, Kasvatustieteellinen tdk, kasvatustieteiden osasto.

95 Nordström, T. (2016). *Tutkimuksellinen maastossa oppiminen*. Pro gradu, Kasvatustieteellinen tdk, kasvatustieteiden osasto.

96 Huttula, Jenna. *Tutkimuksellisuus ja eheyttäminen luokanopettajan työssä*. Kasvatustieteellinen tdk, kasvatustieteiden osasto. Pro gradu työ, valmisteilla.

97 Huttula, Jenna (2017). *Tutkimuksellisuus ja eheyttäminen luokanopettajan työssä.* Kandidaatin tutkielma. Kasvatustieteellinen tdk, kasvatustieteiden osasto.

98 Kervinen, A. (2016). Tutkimuksellisuus ja monialaiset oppimiskokonaisuudet ympäristöopin ja luonnontieteiden kehittämishaasteina. *Ainedidaktiikan symposiumi*, 12.2. 2016. Turun yliopisto. Esitelmä.

99 Havu-Nuutinen, s., Kervinen, a., Uitto, A,Koliseva, A., Pyykkö, L., Väyrynen, T., Luokanopettajien ja opiskelijoiden yhteistyö luonnontieteen opetuksen resurssina. *Ainedidaktiikan symposium* 9.–10.2.2017, Helsingin yliopisto.

100 Havu-Nuutinen, S., Kervinen, A., Laine, A., Uitto, A., ja Väyrynen, T. (2017). Fostering ICT and inquiry enhanced instruction in primary science education: Creating a model of team teaching. *Conference book, ESERA 2017 Conference*, Dublin City University, Dublin, Ireland 21st–25th August 2017. Oral presentation.

101 Uitto, A. ja Nordström, T. (2017). Inquiry approach in the outdoor learning environment. *Conference book, ESERA 2017 Conference*, Dublin City University, Dublin, Ireland 21st–25th August 2017. Oral presentation.

Up until now, Luma ambassadors has been carried out seven times in the Uusimaa region. There have been 14 participating school, 30 primary school teachers (mostly class teachers, but also subject teachers), 42 student teachers (studying to be class teachers), and hundreds of students, mostly from grades 1–6. 2–7 university lecturers have been involved in the project. In the spreading phase of the project in 2017, 4 in-service training sessions have been carried out all over the country, in which there have been 200 participating teachers.

The project is currently a part of the **LUMA FINLAND development program's** project "*From training to school*", in which there are all together 5 university campuses participating all over Finland. Teaching entities for basic teaching have been produced in the project. Material, work instructions and ideas for lessons and instructions for implementation are available for teachers. The material emphasizes the exploiting of ICT and inquiry-based work in the teaching of natural sciences (environmental studies). In teaching, operations are integrated between different subjects. The operating model from the Luma ambassadors project creates a basis for the operations.

(iii) Science and Mathematics in Society: Interdisciplinary Cooperation with Companies

Science and mathematics in society: interdisciplinary cooperation with companies project[102] is a good example of collaboration between the university, schools and companies. It is a good example of teacher education in which pre-service teachers learn from more experienced teachers from schools. In total 14 companies and organizations have participated in the project for 4 years. There have been partners from the Economic Information Office TAT, Finnish Chemical Industry, the field of marketing and forestry, Me & My City and from several companies. In 2017, the course was carried out in cooperation with the University of Ljubljana from Slovenia and professor Vesna Ferk Savec. The University of Ljubljana carried out a similar course in their country for the first time.

The purpose of the course is to get (for the teaching of mathematics and natural sciences): new inspiring and practical examples and applications. The course is a part of future subject teachers' working life studies in the new *Degree Program for Subject Teachers in Mathematics, Physics and Chemistry* at the University of Helsinki on the Kumpula campus[103]. The next interdisciplinary course for the

102 https://maluyhteiskunnassa.wordpress.com/

103 https://wiki.helsinki.fi/display/opetussuunnitelma/Opintojaksojen+tiedot+-+koulutusohjelman+yhteiset+opinnot#Opintojaksojentiedot-koulutusohjelmanyhteisetopinnot-3.Matematiikkajaluonnontieteetyhteiskunnassa

University of Helsinki mathematics and natural science students will be carried out in Spring 2018. There will also be an online course for interested pre-service and in-service teachers and teacher educators as a part of **LUMA FINLAND development program**. The course is also a part of an international science, technology, society and environment (STSE) research project with the University of Ljubjana and a PhD thesis.

The developed course[104] is based on a previous research and the new core curriculum. The aim is to utilize learning environments outside school. In addition, it is important to practice interaction skills that are necessary in school-company cooperation. The course has changing themes like circular economy and water. After a theory part of the course, there is a functional part. In the functional part the pedagogical model is designed, transferred to teaching-material and carried out in cooperation with a multi-professional team, which consists of teacher students of LUMA subjects (different majors), a school and a company which is located close to the school. The collaborative and interdisciplinary teaching material has 3 parts: before the visit, during the visit and after the visit. Any teacher can use the teaching material as it is or apply parts of it.

Visits to companies near schools[105] not only save time and resources of schools, but also make it possible to see and experience things in an authentic environment. In nearby companies, it is possible to have discussions with professionals on why we need chemistry, mathematics and physics in the working life. Examples from everyday life inspire students and teachers to learn and also give information on society and different professions.

(iv) StarT Ambassadors as Science Educators

In the StarT ambassador action model, the aim is to learn together by carrying out interdisciplinary projects. According to previous research, project-based learning is a meaningful way of learning mathematics, natural sciences and technology together. It is possible to unite e.g. science, art, sports and children and youths' interests, in an interdisciplinary way. For students studying at the University of Helsinki, it is possible to include the StarT ambassador training and acting as an ambassador as a part of the Science education course (organized by the Science Education Centre) on the working life studies for the future teachers in math, physics and chemistry (see chapter 5.4.2).

104 Kousa, P., Tuomisto, M., Mustikkaniemi, H., & Aksela, M. (2015). Yhteisöllistä ja eheyttävää opettajankoulutusta: esimerkkinä matematiikka ja luonnontieteet yhteiskunnassa -kurssi. LUMAT, 3(6), 829–837. https://www.lumat.fi/index.php/lumat-old/article/view/103

105 http://suomi.luma.fi/wp-content/uploads/2017/12/Yritysvierailu.pdf

Projects can be carried out in a learning community (it can also be a science club) as smaller and short-term projects, as a separate theme course or as long-term operations from early childhood education to secondary school (these can last for a whole year).

In the open-online Science education course (MOOC), the ambassadors get basic training for the task (e.g. theoretical knowledge on integrated education and project-based learning and practical tips that can be found in the StarT material bank). The length of the task is defined during the education, and the science education course consists of reporting and assignments. The StarT ambassadors operate within the StarT program and support participating learning communities and especially children and youth performing projects, and while they are instructing they have the opportunity to learn from children and youth. They can support for example by helping in carrying out the projects, by arranging a visit to a place that is crucial for the project, arranging a lecture from a specialist, organizing a workshop or just bringing another set of hands to help alongside the teacher.

The StarT ambassador support model is a part of LUMA Centre Finland's StarT program[106]. The aim of this model is to enable support for everyone carrying out StarT projects in Finland. University students are not the only ones, who can act as ambassadors, also for example parents, specialists and StarT's cooperation partners and companies can be ambassadors.

5.2.5 Examples of Cooperation between University Teaching and Science Education

In addition to teacher education, science education of the Centre is also connected to other teaching at the university and its development. The new solutions and innovations produced here, have been applied to university teaching. For example, inquiry in **chemistry** teaching at the university level has been developed on the basis of research in chemistry education, and especially problem-based learning (PBL) has been developed[107].

University teaching on mathematics, at the University of Helsinki, has a long tradition of cooperation between mathematical science education (the operations of Summamutikka), development of teaching of mathematics at the university level and math subject teacher education. These form the interactive "triangle".

Previous, inspiring experience from children's Math Days has taught how hands-on activities and the offering of meaningful experience, open mathematics

106 https://start.luma.fi/en

107 Rautiainen, J. (2012). Kehittämistutkimus: Ongelmalähtöinen kokeellinen korkeakouluopetus. Helsinki: Helsingin yliopisto. http://urn.fi/URN:ISBN:978-952-10-8149-1

to the children. In addition, discussions with children reminded in many ways of discussions between adult mathematicians. A question was raised from this: could the teaching of mathematics in school and at the university be based on finding significance.

Later on, subject teacher education in mathematics and teaching of mathematics at the university has been developed actively with the Summamutikka science education operations. The developed operating models from this one "tip of the triangle" will move naturally towards the other two "tips of the triangle". For example, the above-mentioned experiences on the Math Days led to ideas that acted in the background when the teaching of a first-year analysis course was renewed[108].

On the other hand, in the university teaching of math, a new method was developed in 2011. This is the Extreme Apprenticeship method,[109] that was produced for the teaching of computer sciences, but that was transmitted from the renewed university teaching of computer sciences. Later it has been also applied to school teaching (for example in the Mäkenlänrinne upper secondary school in Helsinki). You can read more on the topic on the website[110] of a research group for the teaching of math.

In addition, for example with the GeoGebra, a course aimed at teacher students and in-service training offered by the Science Education Centre (a part of the LUMA FINLAND program) were in close cooperation together. Many Master's Theses in teacher education of mathematics and doctoral dissertation projects on the research of the teaching of math are connected to science education in mathematics or the development of university teaching of mathematics.

Themes in programming, and more widely in data processing and information networks, have lately been incorporated into the Finnish school curricula. There is no formal teacher training program in computer science at the University of Helsinki. The Science Education Centre is thus one of the main forums in which teachers' education on this subject can be developed and propagated. We support teachers of different subjects – and especially mathematics teachers – in acquiring the skills necessary to teach programming to students, but also to help students find suitable applications for their programming skills, and to transmit an edifying view of the societal importance of computer science and related fields (for example through potential new professions arising from the field).

108 Oikkonen, J. (2009). Ideas and results in teaching beginning maths students. International Journal of Mathematical Education in Science and Technology, 40(1), 127–138. http://www.tandfonline.com/doi/abs/10.1080/00207390802582961

109 Vikberg, T., Oinonen, L., & Rämö, J. (2015). Tehostettu kisällioppiminen matematiikan yliopisto-opetuksessa. Yliopistopedagogiikka, 22(1). https://lehti.yliopistopedagogiikka.fi/2015/03/26/tehostettu-kisallioppiminen-matematiikan-yliopisto-opetuksessa/

110 http://blogs.helsinki.fi/mathedgroup/

It is essential that an interactive relationship is built with those teachers (and schools) that have a need for a wider consensus view on pedagogical interpretations and approaches, on the skill levels expected and on the tools used to achieve these. The availability of learning materials in the subject is still limited, and therefore the products of LUMA projects and cooperation with schools play a significant role.

The Ready, Steady, Gradu! Think Tanks of **humanities** have been organized so that students and researchers would meet in an interdisciplinary way. The aim of these think tanks is to help subject teacher students of foreign and domestic languages to come up with significant themes for their theses – including Bachelor's and Master's Theses. At the same time researchers have a chance to tell students about different research projects, which are perfect to write a thesis on. In the field of science education of humanistic subjects, theses have been written e.g. on the teaching and development of different areas of language skills and on teaching methods and materials of different subjects.

5.3 New Training Models for Teachers' Lifelong Learning

The supporting of teachers' lifelong learning is one of the purposes of science education of the Centre. Various models for supporting it have been developed [111] [112] over the years, such as:

1. Long-term (1–3 years), hands-on training projects, during which the trainees are in active interaction between each other and the specialists of the university.
2. Courses for pre-service teacher education at the university, in which also teachers at the field can take part in (the courses are carried out so that there is a contact teaching part and an online part).
3. Interactive courses that are done completely online e.g. Massive Open Online Courses or MOOCs.
4. Working in a StarT learning environment, or carrying out learning projects (that follow the concept of StarT) in own teaching, sharing of own ideas and achievements and reflecting on them in communal StarT events and online both nationally and internationally.
5. StarT ambassadors and LUMA ambassadors (university students) are on the spot in different level learning communities to help teachers and to give them new ideas and models from the university, for example the LUMA ambassador project.
6. When bringing their teaching groups for a science lab visit, teachers meet teacher students as well as other students and specialists of the university (networking), and when they observe the visits they get to know new ideas, materials and models and how to apply them.
7. Afternoon science clubs that take part in the facilities of a learning community, the teachers of the community can take part in them (although the future teacher students will be the ones who mainly instruct the children).
8. National LUMA Days and International LUMAT Symposiums (bulletin lectures, pedagogical cafes, workshops) as forums for sharing and networking, organized once a year.
9. Single, short workshops in the evening or weekends e.g. on a requested topic
10. Individual, live and therefore interactive specialist bulletin, or specialist bulletins that have been saved online (webinars), e.g. LUMA TV

In connection with the Science Education Centre, training for different level teachers that promotes their lifelong learning, has been organized along the years. It has been funded mainly by the Finnish National Agency for Education and the Magnus Ehrnrooth Foundation. Training has been organized in different forms and these have been described at the beginning of this chapter (chapter 5.3). Thousands

111 Juntunen, M. (2015). Holistic and Inquiry-Based Education for Sustainable Development in Chemistry. Helsinki: Helsingin yliopisto. http://urn.fi/URN:ISBN:978-951-51-1753-3

112 Tomperi, P. (2015). Kehittämistutkimus: Opettajan ammatillisen kehittymisen tutkimusperustainen tukeminen käyttäen SOLO-taksonomiaa – esimerkkinä tutkimuksellinen kokeellinen kemian opetus. Helsinki: Helsingin yliopisto. http://urn.fi/URN:ISBN:978-951-51-1753-3

of teachers from different levels have participated in training. Descriptions of these can be found in the annual reports. A few training projects that inspire and support lifelong learning have been described in the following part (the trainings are mentioned in alphabetical order).

5.3.1 Formative Assessment in Science Education

The formative assessment training model is a good example of teacher educators at the university working together with school teachers in developing new and meaningful solutions and pedagogical innovations, based on the research knowledge and positive experiences, and sharing this information for the community. The training model has been formed, because of a need: numerous teachers have had the need to get new methods in order to support learners' learning process in a interdisciplinary way, and to strengthen science skills. On the other hand, researchers at the university have had the need to understand in more detail how to support the learning of concepts and phenomena with the help of methods of formative assessment. Also, the method of action research has been used in the model.

This new kind of in-service training model was launched in 2016, in order to find new ways of execution and testing for formative assessment. The purpose of this training model has been to collaboratively find different kinds of ways in which to support a student's learning through formative assessment. The new Finnish core curricula especially emphasizes formative assessment to direct learning. In this model, the teachers' requests and needs as well as previous experiences and good models have been taken into consideration, while creating the program and its contents. The teachers participated in this project, because they have been interested in it, and they also have often spent their free time in the project meetings.

In this collaborative training model, chemistry and physics teachers from lower- and upper- secondary education as well as vocational schools all around Finland have first, together with the teacher educators, learned theory of formative assessment and its opportunities, also the possibilities of ICT. Then, the teachers in their schools have tested and developed formative assessment with the beforehand chosen methods. In mutual sessions, the teachers have presented their experiences to each other on different methods and their ways of implementation. The results have been comprised by using an action research method on the results. In collaboration, everyone learns from one another, also teacher educators.

The results gathered in this in-service training model have been presented and will be presented in the national LUMA Days. Also, a mutual publication, where the best practices are shared, is going to be published in the near future. An article

has been written on the topic in a publication of the Finnish National Agency for Education about inquiry-based learning and possibilities of ICT.[113]

5.3.2 GeoGebra – Virtual Training

GeoGebra training is an example of a good implementation model of virtual training on science education in mathematics. **GeoGebra** is a part of the LUMA FINLAND development program's "Meaningful mathematics" project at the University of Helsinki (the program is funded by the Ministry of Education and Culture) (see chapter 3.2.1).

With in-service training in mathematics, it has been wished to reach an even broader participant group. Therefore, such a training has been developed that is done completely online, which then makes it possible to participate regardless of the time and place. The theme for an online training has been chosen. It is a current and a popular theme in trainings that are based on contact teaching: the GeoGebra software and using it in teaching.

The first GeoGebra online training was organized in the Spring of 2015. The structure of the training and contents have been developed during the years, by feedback from the participants, but the purpose has always remained the same. The purpose of the training is to teach the basic features of the GeoGebra software to the participant and to offer plenty of practical and concrete examples of using GeoGebra in teaching. The training is aimed for math teachers of primary and secondary schools.

113 Herranen, J., Koljonen, T., Aksela, M. (2017). Tutkimuksellinen opiskelu ja formatiivinen arviointi luonnontieteissä. Arviointia toteuttamassa: näkökulmia monipuoliseen oppimisen arviointiin. Toimittaja: Eija Kauppinen, Erja Vitikka. Helsinki. Opetushallitus. 114–126

Figure 28. The themes of the math training vary from hands-on mathematics and from the essential mathematical concepts into using ICT in the teaching of math. In the hands-on math training, it is possible to explore different teaching and observing materials of math, and their usage (Picture: Rajka Kavonius)

5.3.3 An In-Service Training Project for Language Teaching

An in-service training project for language teaching is a good example of how language teachers are supported in current challenges in language teaching, by exploiting newest research information. The materials of the training have been shared online, they are available to everyone.

In-service training has been organized in the humanistic subjects, mainly for language teachers in questions concerning speech communication, listening skills of teachers, using ICT in language teaching and in developing inspiring teaching methods.

For example, in 2014–2015, an in-service training "Inspiring Swedish with the help of immersion techniques" (1 ECTS) was organized especially for Swedish teachers (for teachers teaching Swedish in 6th grade). The material for the training was uploaded online[114]. In 2015–2016, a training "Swedish in an encouraging way, functionally and collaboratively" (2 ECTS) was organized for teachers of Swedish in primary and upper secondary schools as a part of a project "Tools for challenges

114 http://blogs.helsinki.fi/innostavaaruotsia/

that Swedish teachers encounter in daily work". The training was funded by the Finnish National Agency for Education, and therefore it was free for the participants, the teaching personnel. The material was uploaded online[115].

Figure 29. In science education in humanities, teachers are supported in teachers' current questions concerning language teaching, by exploiting newest research information. In the picture, language teachers are refining their teaching skills together in in-service training. (Picture: Mika Federley)

5.3.4 Trainings of the LUMA FINLAND Development Program

In the Science Education Centre, there are eight projects that are funded by the Ministry of Education and Culture and that belong to the LUMA FINLAND development program (see chapter 3.2.1). Their purpose is to support teachers in basic education in using new core curriculum and by doing this, strengthen their science skills. You can find more information on each of these projects and on new materials on their websites. They are meant to be used broadly in basic teacher training (pre-service education). A couple of training projects are presented (in alphabetical order) here:

***A good question! project*:** the areas of development are methods that use students' own questions in teaching[116]. The methods of this project have been tested and developed together with class teachers in grades 1–6. From this, support material

115 http://blogs.helsinki.fi/ruotsinope/

116 Herranen, J. & Aksela, M. (2015). Oppilaiden kysymykset oppilaslähtöisessä luonnontieteen opetuksessa. LUMAT, 3(7), 999–1004. https://www.lumat.fi/index.php/lumat-old/article/view/120

for teachers has been developed so that teachers could support the inquiry-based method[117]. A training session is organized on the project for example in the form of a MOOC course together with the LUMA Centre of the University of Eastern Finland in 2018–2019.

Everyday life phenomena project: offers models and materials for integrated chemistry education that are interdisciplinary and take the different learners into consideration. The models and materials have been developed and tested in cooperation with teachers in order to support the teaching of chemistry in the everyday life context by using newest research information[118]. The aim of this project is to support teachers in carrying out integrated science education in a meaningful way and according to the regulations set for teaching, and at the same time to support students' transversal competences. An online course in the project is organized in 2018–19 in cooperation with the national StarT program.

Meaningful math project: consists of a GeoGebra training project (see above), a virtual math club, Mathversum, that is offered to children and youth and Pulmaario workshops on mathematics and programming that are held in libraries. Training for teachers on these is organized in 2018–19.

5.3.5 Molecular Gastronomy in Science Education

This in-service training model is unique as a science education project both by its theme and its way of implementation. This project focused on a theme that was just making its way to the public. In this project, different subject teachers' skills were put together by following the principles of inquiry-based learning and by exploiting newest research information. At the University of Helsinki, the theme of chemistry in the kitchen has been a part of chemistry teacher education for nearly twenty years.

Perennial in-service training (2012–15) on molecular gastronomy as a context for lower- and upper-secondary education gathered around chemistry teachers and home economics teachers from all over Finland. The purpose of this in-service training was to promote research-based science teaching in the context of molecular gastronomy, and by doing this, to inspire 13–19 year-old adolescents to study and understand scientific phenomena in everyday life, especially in the context of cooking and baking. In the instruction of specialists from the University of Helsinki and professor **Anu Hopia**, the teachers were able to learn more about molecular gastronomy. They took part in various workshops instructed by the specialists (e.g.

117 https://hyvakysymys.wordpress.com/

118 https://arjenkemiaa.wordpress.com/

MG chefs), learned some theory, brainstormed, tested and developed new teaching material[119] [120] [121], which was published as an e-book[122].

A part of the trainings was funded by the Finnish National Agency for Education.

5.3.6 Meaningful Pedagogical Use of Technology in Hands-on Teaching

In this training project, such a model was tested for the first time in which teacher educators from different universities, planned the training together and trained teachers mainly online. This online training consisted of many different modules. During the implementation of these modules, data produced together and/or good pedagogical practices on the teaching of LUMA subjects that arose from the schools during implementation, were collected online[123].

The project, funded by the Finnish National Agency for Education, was carried out in 2015 in a collaborative project of the LUMA Centre Finland network.

5.3.7 Other Training Projects: From Summer Courses to MOOCs

Since 2003, numerous training sessions that support teachers' lifelong learning have been organized. Nowadays, the in-service trainings are organized mainly as online trainings (MOOCs, see below). The role of the university in the trainings is to bring new research information and pedagogical innovations as a meaningful part of science education. Training has been organized as broader courses, **summer courses and workshops** during the school year. For example in science education of physics, an inspiring summer course on physics was carried out on various themes. The instructors were teacher trainers in physics, top researchers and specialists. In the *Chemistry Today* project of chemistry teachers, Finnish Chemical Industry, the Finnish National Agency for Education and science education of chemistry worked together. The project lasted for a couple of years.

119 Motturi, H., Slawuta, S., Salkunen, S., & Rajala, P. (2013). Plant pigments as pH indicators in cooking. LUMAT, 1(2), 209–218. https://www.lumat.fi/index.php/lumat-old/article/view/185

120 Ollila, A., Aho, T., Helminen, T., Helppolainen, A., Mäkelä, K., & Pulkkinen, V.-P. (2013). Concept of solubility, soft drinks and pectin jelly. LUMAT, 1(2), 219–228. https://www.lumat.fi/index.php/lumat-old/article/view/186

121 Sirén, R., & Vuorikoski, A. (2013). The concept of emulsion and salad dressings. LUMAT, 1(2), 229–232. https://www.lumat.fi/index.php/lumat-old/article/view/187

122 Tuomisto, M., Hopia, A., & Aksela, M. (toim.). (2015). Molekyyligastronomiaa kemiaan ja kotitalouteen: opetuskokonaisuuksia yläkouluun ja lukioon. https://www.e-oppi.fi/kirja/molekyyligastronomia/

123 http://www.luma.fi/opettajille/sahkoisia-materiaaleja/aineistoja-ja-hyvia-kaytanteita-teknologian-mielekkaaseen-pedagogiseen-kayttoon-luma-aineiden-toiminnallisessa-opetuksessa/

When planning in-service trainings, the teachers' needs are taken into consideration and a training entity that supports these needs is produced together by using newest research information. The themes for the trainings have been:

- Getting to know the world of atoms and molecules by visualizing
- Adventure in astronomy
- Differentiation in teaching of LUMA -subjects
- The wind of change of genetic engineering
- Human physiology
- Chemistry in the working life
- Learning games in chemistry
- Vividness into physics and chemistry by narration
- Sustainable chemistry and virtual learning environments
- Inquiry-based physics for class teachers
- Physics of the earth and air
- Looking for essential mathematics
- Mathematics by doing arts, moving and playing
- What do we need mathematics for?
- Why is this so difficult? The difficult themes in upper secondary level math
- Where do we get energy in the future?
- How do we carry out natural sciences and how is it produced?
- A changing view of the world and new findings in cosmology
- Modern websites
- Learn game programming and its usage in teaching
- Geographical Information System (GIS) supporting teaching
- Game programming in upper secondary school
- Math tree of primary/ lower secondary school
- Cans in the right place – recycle waste
- Virtual learning environments in LUMA -subjects
- Natural science education that is functional and takes place outside class
- Functionality into teaching of primary school chemistry
- Functionality to math lessons
- Inquiry-based learning of chemistry in upper secondary school
- Inquiry-based teaching and green chemistry
- Occupational safety in chemistry teaching
- Renewable energy in the modern society
- Inquiry-based work dealing with water and the environment

Virtual and interactive MOOCs act as forms of in-service training even more in the future (see the LUMA FINLAND development program's courses described earlier and international virtual courses and symposiums on the education of sustainable development). They are available to all Finnish teachers and to those who are interested, including future teachers.

For example, the **Linkki lab** offers online support for teachers who wish to learn programming. Teachers can take part in programming MOOCs and thus develop their **programming skills** as well as their skills in teaching programming. There are also open online classes offering guidance in the use of different programming environments in teaching. Further in-service training is organized in cooperation

with partners, who have existing responsibilities in organizing teacher training, and also directly with schools.

The in-service teacher training materials used by Linkki are similar to those used in the courses for teaching programming in the Department of Computer Sciences at the University of Helsinki. The emphasis, in these courses, is on transforming the core concepts in the national school curriculum into key concepts and concrete methods that students are able to master. The learning environment is developed through different pedagogical theories and methods from formative assessment models. Course participants work in groups to create their own teaching materials for classes on programming concepts and their assessment. In some cases participants already know the school they will be training or working in, so these materials will be directly implemented in the classroom.

5.4 New Science Education Training for University Students

For the different forms of science education (e.g. science clubs and camps) of the Centre, training has been organized for future teachers since 2003 as contact teaching and also online. Here, two operating models have been described on how to organize training.

5.4.1 A Course for Instructing Science Clubs and Camps

The first course for the instructing of science clubs and camps was planned and organized in cooperation with the Development Centre Opinkirjo in 2013. The structure of the course consisted of lectures[124], working in homegroups, having meetings with mentors, and instructing a test group (Figure 30).

124 Material e.g. Tiede- ja teknologiakasvatus. Laatua asiantuntevasta kerhotoiminnasta. (2016). Helsinki: Katajamäki Print & Media. (Also in Estonian: Arenev teadushuviharidus. Õpime kogemustest. (2016). Helsinki: Katajamäki Print & Media.)

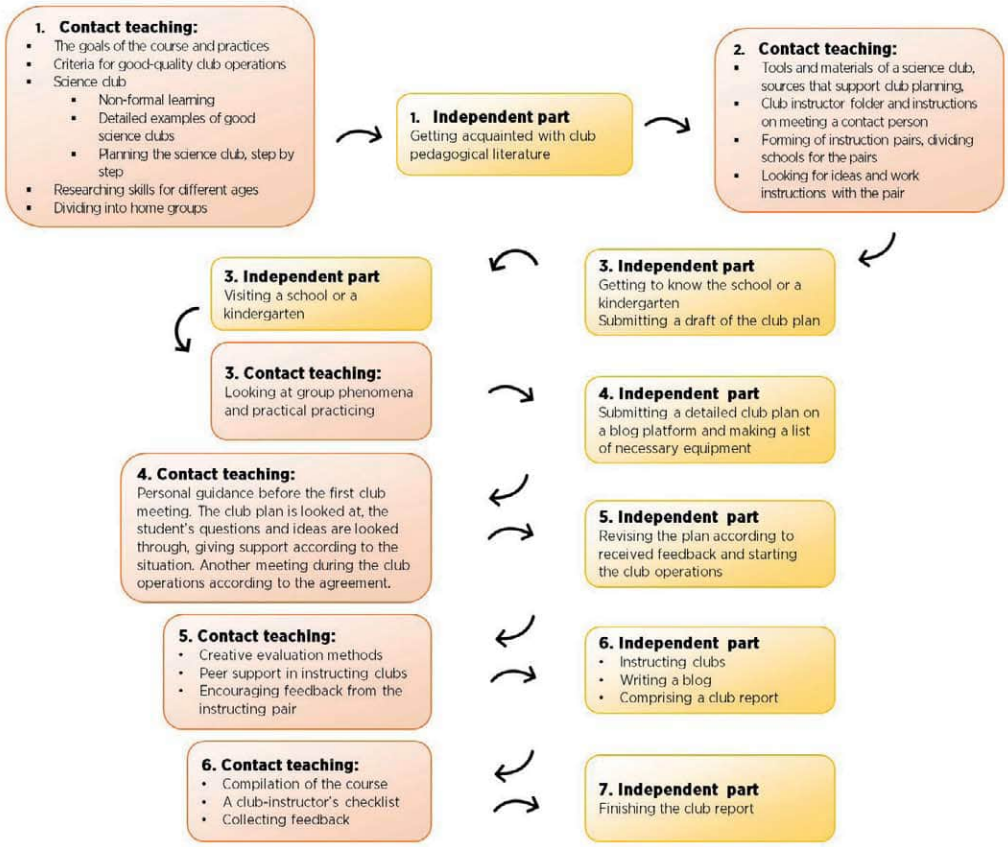

Figure 30. The development of science education is carried out in cooperation with different partners and universities (see 5.4.2). Here is the structure of the course (that was developed together) for instructing science clubs and camps.

5.4.2 A New Course on Science Education with the Model of Merging Education

Science education is aimed at being strengthened all over Finland as a part of university education. Students of the University of Helsinki and future teachers are being trained to become experts of science education and operators according to the model of merging education through a **Science Education course** (5 ECTS). The course consists of an online part (2 ECTS) and a practical part that can be chosen from the science education module, and exercises concerning the topic (3 ECTS). The course is a part of working life studies for the new *Degree Program for Subject Teachers in Mathematics, Physics and Chemistry*. The course is researched and developed as a part of dissertation work.

Figure 31. The MOOC platform for an online course on science and technology education. Anyone interested on the topic, can complete the course. The aim is to get different forms of science education into wide use all over Finland (the so called "science club in every village")

The online part of the course (MOOC) that is open to anyone interested, consists of common parts that deal with working with children and youth and optional modules, from which the participant of the course can choose the most interesting ones. Various optional modules are for example: instructing a science or technology club for different ages, acting as a StarT ambassador or a LUMA ambassador, and instructing visits of school groups in science and technology labs.

The project started operating as a part of the implementation of the national task of the LUMA Centre Finland network. The online course is marketed and recommended for university and secondary school students as well as in-service teachers already in the working life, club instructors, parents and grandparents, different specialists of organizations and for anyone interested on the topic.

6. NEW APPROACHES IN SCIENCE EDUCATION FOR CHILDREN AND FAMILIES

In this chapter, different kinds of research and development environments in the science education for children and families are being described (see Figure 27). At the same time through these, the aim is to inspire children and youth towards studying sciences, according to the aims of the operations of the Science Education Centre (see the aims in the Foreword section).

6.1 Operating Models

In different operating models of science education of the Centre (see Figure 32), new solutions and pedagogical innovations are being developed into science education on the basis of research. All the main forms are described briefly in the following chapter with pictures.

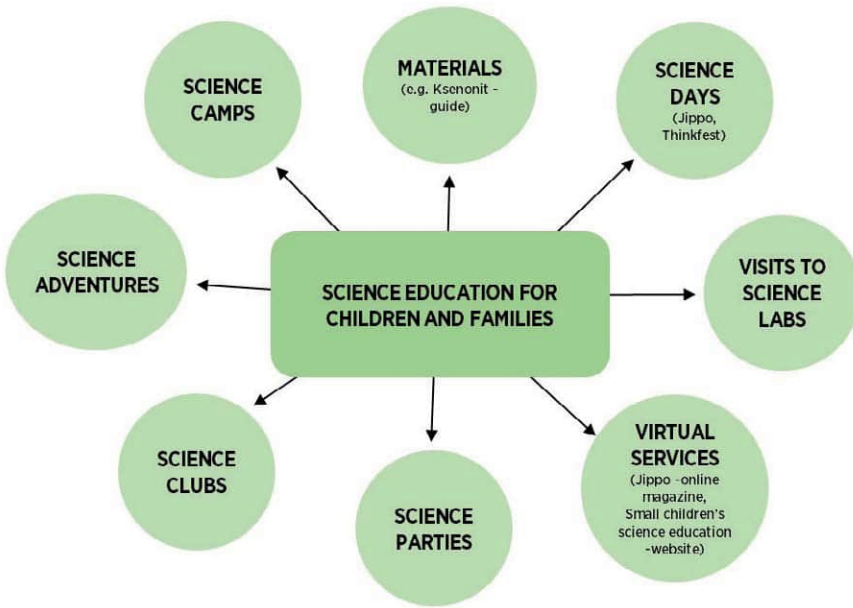

Figure 32. Forms of science education for children and entire families that operate or have operated as research and development environments for science education, as far as thematic focus areas and ways of implementation are concerned (see chapter 1).

6.2 Models for Science Clubs

Science clubs have been organized since 2003 as interdisciplinary and as focusing on an individual field of science. They have been organized both at the university as well as in other learning environments (kindergartens, schools, libraries), and also virtually. Some of the best operating models of physical science clubs have been described here (some focusing on one subject, some interdisciplinary): **clubs focusing on a specific discipline** (chapter 6.2.1) and **interdisciplinary clubs** (chapter 6.2.2).

In the future, family clubs (**family science education**) are going to be developed even more on the basis of research. It has been a part of the program of the existing clubs: family members or grandparents have participated together with their child at the club or at home through virtual operations.

6.2.1 Discipline Specific Clubs

This chapter looks at science clubs on specific subjects and models that have been developed in them. The themes for the science clubs include mathematics, programming and chemistry, which have been carried out for quite a while in science education and a part of its pre-service teacher education.

(i) Math Clubs

There is a long tradition of organizing math clubs. The popular clubs are organized in school facilities all around the Helsinki region. They are held mainly in the afternoons after school days. The clubs meet once a week for 1,5 hours for a total of 6 weeks.

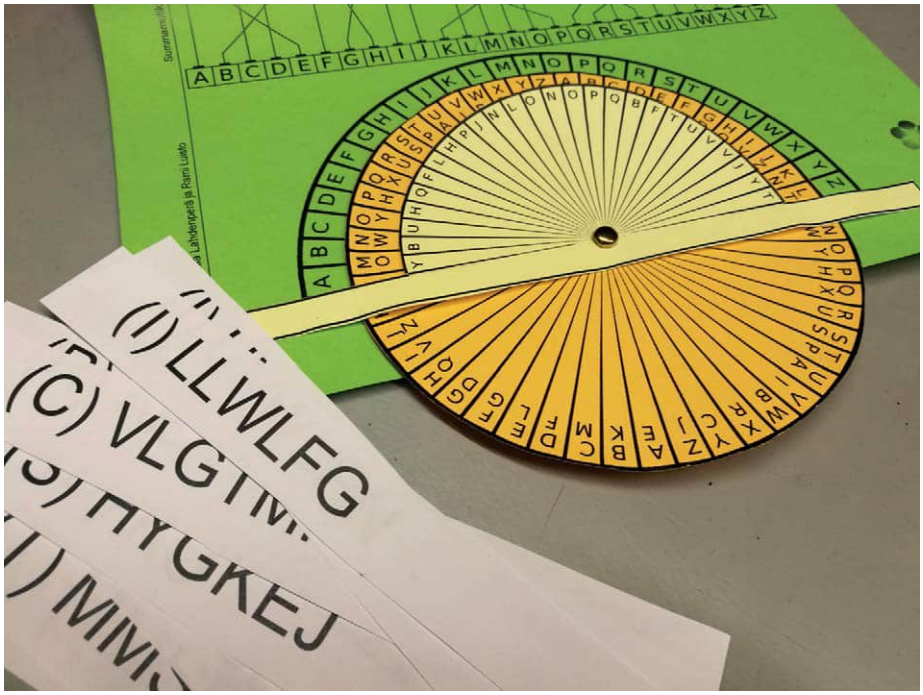

Figure 33. Would you be able to solve the encrypted words with the help of this Enigma machine that has been made out of paper? In the math clubs, it is possible to e.g. play detectives and to explore different methods of encryption (Picture: Jenni Räsänen).

The clubs are instructed by university students that have received training for acting as instructors. The instructors plan and carry out the program themselves. The clubs usually have some kind of a theme or a common thread, so that the activities build a coherent entity. For example, a theme for the club can be detectives or famous mathematicians.

The best ideas for clubs have been comprised into an e-book[125], so that teachers and other operators would be able to organize math clubs independently. There you can find club reports written by the instructors, which can be freely used for organizing own clubs. Club training is currently a part of the Science education online course (chapter 5.4.2).

Along the years, math club operations have been supported by e.g. the Technology Industries of Finland Centennial Foundation.

125 http://blogs.helsinki.fi/summamutikka/

(ii) (Game) Programming Clubs

The Linkki Science Lab (LUMA lab) of the Science Education Centre has organized programming clubs all through its existence. The themes for the clubs come from subjects that interest children and youth, such as game programming. Storytelling is also a tool well suited for programming tasks, which makes it easy to integrate different fields of science and cultural phenomena into the clubs.

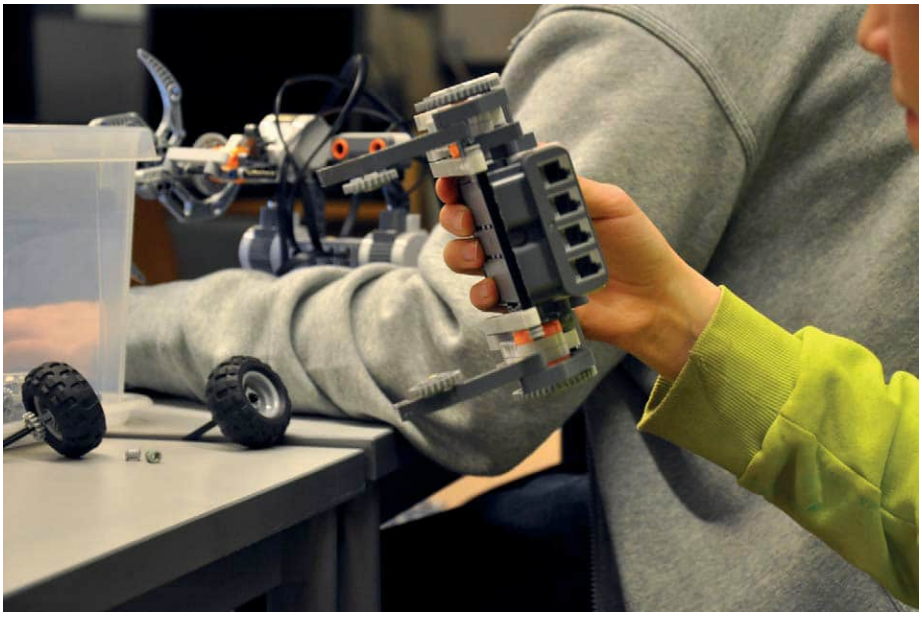

Figure 34. In a robot programming club, mechanics and building skills are also at work. (Picture: Hanna Aarnio)

Like the math clubs, programming clubs meet on a weekly basis. The programming tasks from different weeks build upon each other to form a toolkit of basic programming skills. The focus of a specific club varies from core programming skills to robotics and interdisciplinary clubs organized with other LUMA science labs.

All skill levels are served by these programming clubs, starting from those still learning elementary computer usage skills such as using the mouse. Visual programming environments are well suited for learning basic programming skills, but also more complex structures can be implemented through graphical methods. More advanced young programmers progress to text-based programming. Secondary school students, who already understand the core concepts in the primary school curriculum, find more challenging work in algorithmic problem-solving tasks and projects. These are particularly useful in bringing out the applicability of algorithmic thinking in solving problems from also other fields of science.

Programming skills help in understanding the ways scientific phenomena are represented in simulations, as well as with using computational models to analyze problems and contemplating concepts in artificial intelligence and data analysis. As the skill set of a young programmer expands, fields such as competitive programming become feasible goals. Some club participants have progressed as far as going through materials on university level programming courses.

The national Datatähti ("Data star") programming competition[126], coordinated by the national mathematical subjects' teacher association MAOL, is aimed mainly at upper secondary school students, but is open to younger students as well. The best performing students are invited to join a team coached by university experts. The team then prepares for international competitions, such as the Baltic Olympiad in Informatics (BOI) and the International Olympiad in Informatics (IOI).

Programming club participants have also experienced the university as a working environment through visiting researchers. They have also learned more about the profession of a game programmer through visits from game companies. The effect that these after-school clubs and collaborations with schools have had on the university community is also noticeable. Especially, many of our international researchers have been inspired by the eager young programmers, who take over the computer labs after the work day. Researchers have had the chance to develop as communicators through club collaborations. All the while, programming clubs have offered an important opportunity for teacher students to gain experience in teaching programming.

Research data is continuously collected from clubs, especially concerning the development of the participants' self-efficacy and attitudes. In previous research, it has been observed that a programming hobby has a positive impact especially on girls' understanding of their own skills, and their attitudes toward the field[127].

The clubs also operate as testing and researching environments for the learning models and materials produced by Linkki. These are, in turn, openly available for teachers to use.

(iii) Chemistry Clubs

Chemistry clubs have been organized as a part of science education at the University of Helsinki since 2004. The operations were started with a **Ksenonit virtual club**, for which a website "Ksenonit" (Xenons) was established (see chapter 6.5 as well). Its' purpose is to support inspiring learning of chemistry all around Finland. It was used widely as material also in class teacher education.

126 http://kisakoodaus.fi/

127 Hjelm, E. (2016) Tytöt, pojat ja tietojenkäsittelyn opettaminen. Pro gradu. Helsingin yliopisto. https://helda.helsinki.fi/handle/10138/162056

Figure 35. An inspiring **Ksenonit** website was the first virtual project of science education at the University of Helsinki. After this inspiring project, the **Jippo** online magazine has been produced for children's science education and as its part a small children's **virtual club** model.

Research has been a part since the beginning of the virtual operations. The development of the first virtual club was connected to a Master's Thesis[128]. There it was researched, what kind of inquiry-based work in the online environment support an inquiry-based approach and how inquiry supports the learning of chemistry. The activities of the club include e.g. chemistry connected to water's surface tension and to the features of the soil. A guide that was developed based on the **Ksenonit club** is still available online[129]. It contains numerous great ideas for learning chemistry in an inspiring way with children.

128 Nurminen, E. (2005.) Tutkiva lähestymistapa lasten kemian oppimisen tukena Ksenonit-virtuaalikerhossa. Helsinki: Helsingin yliopisto. http://www.kemia.ovh/ont/nurminen-e-2005.pdf

129 http://www.helsinki.fi/kemma/data/KsenonitKemiaaTutkienJaIhmetellen.pdf

Figure 36. Chemistry science clubs are a subject of research and development in science education in chemistry, but also a part of learning environments for teacher education in chemistry. In the first picture, the participants of the club are studying what the soil consists of. (Picture: Veikko Somerpuro). In the second picture, in a StarT science club called "Chemistry and Art", children are making refrigerator magnets out of starch (Picture: Pipsa Blomgren).

Numerous science clubs in chemistry are held yearly, mostly in the ChemistryLab Gadolin. Since 2008, 2–4 clubs have been organized every term for pupils. They have been a part of inquiry-based development of science education in chemistry as well as teacher education. The instructors of the clubs are usually future chemistry teachers. The clubs meet once a week for a period of six weeks, where one session is 1,5 hours long. They have been organized with various themes such as **a detective club, mystery club, tasty molecules and material club.** For example in the mystery club, in every session children figure out a clue connected to the mystery and at the last session, they are able to solve the mystery with all the clues they have figured out.

The clubs have been very popular, and a major part of the participants would like to take part in the next club. In order for children and youths to be able to continue their chemistry hobby after participating in one club, the club program is being developed in a continuum. In the future, especially family clubs are going to be a subject of research and development.

6.2.2 Interdisciplinary Science Clubs

This chapter looks at good models for interdisciplinary science clubs: (i) **small children's science clubs for 3–6 year-olds** (both physical clubs and a virtual club), (ii) **Pulmaario workshops on mathematics and programming** and (iii) **Chemistry and Art science club** as a part of a collaborative project with the Finnish Union of University Professors.

(i) Small Children's Science Clubs

At the beginning of 2013, a research and development project on small children's science education was launched at the Science Education Centre. In this project, science clubs for 3–6 year-olds were a subject of research and development. A doctoral dissertation has been made in the research group, concerning the topic (Jenni Vartiainen, 2016).

The following areas have been a part of a project on small children's science education:

(i) **development of a science education model for 3–6 year-old children,** based on research[130]. In the project, children's researching skills, especially skills

130 Vartiainen, J. & Aksela, M. (2013). Science clubs for 3 to 6-year-olds: Science with joy of learning and achievement. LUMAT: International Journal on Math, Science and Technology Education. https://www.lumat.fi/index.php/lumat-old/article/view/180

of observation and children's questions have been researched. This research has been a part of the above-mentioned research concerning the doctoral dissertation.

Numerous clubs have been organized for both 3–4 and 5–6 year-old children, and teacher students have participated in instructing these clubs. The clubs also have functional homework. In small children's Jippo clubs, Jippo together with professor Somersault and the other characters, have led children to the wondrous world of research by using stories and drama. The themes for the clubs were hands-on mathematics and natural sciences. The club program consisted of science, art, feelings and technology in a interdisciplinary way. The purpose was to give all children the joy of insight and success as well as experiences. Children's questions and their wondering were central in the operations of the club. In the pilot phase of the club, parents and anyone interested were given the chance (during the club meetings) to receive information and discussion possibilities about children's science and technology education e.g. how to support the child in questions about science and technology and during inquiry done at home.

(ii) **Small children's science education as a part of kindergarten curriculum** (in the research project, the opportunities and challenges of science education were researched in the operations of kindergartens. This was done also by researching kindergarten teachers' experiences; the results have been published as a part of the dissertation[131] The model has been spread around and is applied now into a part of the operations of kindergartens. The positive experiences and material that was received in small children's science clubs was exploited in the implementation.

(iii) The development of **the virtual club model** on the basis of research as a part of families' mutual hobby taking part at home. A virtual club model was developed in the research project, in which families together carried out inquiry-based work at home with videos as their guides. The children's research results were either videoed or photographed and they were shared for all participants of the club to see. In this research, parents were researched on the challenges of virtual club operations.[132]

(iv) **Small children's science club operating model** has been developed further since the Fall of 2017[133]. In the model, an interesting story, using all the different senses and wondering, play a key role. In order to support the organizing of

131 Vartiainen, J. (2016). Kehittämistutkimus: pienten lasten tutkimuksellisen luonnontieteiden opiskelun edistäminen tiedekerho-oppimisympäristössä. http://urn.fi/URN:ISBN:978-951-51-2658-0

132 Vartiainen, J. & Aksela, M. (2018). Julkaisu virtuaalisesta tiedekerhotoiminnasta vanhempien näkökulmasta valmistumassa.

133 Ideas for science education for small children: https://www.helsinki.fi/fi/uutiset/opetus-ja-opiskelu/uusia-materiaaleja-ja-tukea-innostavaan-lasten-tiedekasvatukseen

these clubs, new material has been produced, such as research bags and functional club carpets. This science club has been organized at the Think Corner of the University of Helsinki, once a week for seven weeks. The children got to research different things such as colors, noise, structures, water and air with the help of the LUMA fox. Small children's club operations are a part of the Science education online course.

Figure 37. Small children's science education project is a part of research of the Science Education Centre. In the picture, the small participants are wondering about different colors. (Picture: Merike Kesler)

(ii) Pulmaario Workshops on Mathematics and Programming

An innovative **Pulmaario project** was carried out in 2014–16 in cooperation with the Helmet network (Helsinki Metropolitan Area Libraries) and with the Science Education Centre at the University of Helsinki. From the Science Education Centre, two science labs were participating in the planning and implementation parts: Math Lab Summamutikka and Linkki Lab of computer science. In the project, workshops on mathematics and programming were planned and organized, and the workshops were held in local libraries. The workshops are aimed at 9–13 year-old children and youth, and the workshops were instructed by university students in cooperation with the library staff. During this project, 20 series of workshops were organized in 17 different libraries.

The aim was to create a self-sufficient workshop model that could be run by library staff themselves. **The Pulmaario Practical Guide**[134] was created to achieve this goal. In addition to the workshop program, the Practical Guide includes instructions and tips on the practical details of running a maths and programming workshop. In the Spring of 2017 the project team visited numerous libraries around Finland in order to train library staff in running their own workshops. Pulmaario starter packs were also sent to libraries around Finland. These packs included the

134 http://pulmaario.luma.fi/en

necessary materials for a series of five workshops, in order to make it easier to get started organizing the workshops.

In addition to training and instructing library staff, **the Pulmaario workshop model** is propagated through training upper secondary school students to act as instructors in workshops for primary school students. After their training the students run workshops in small groups. Through these new operational models we hope to advance the Pulmaario workshops throughout Finland, enabling children and young people to engage in science activities regardless of where they live. This project is a part of research of science education in mathematics.

Figure 38. The atmosphere in a Pulmaario workshop (Picture: Maija Pollari)

(iii) Interdisciplinary Science Clubs

Learning about science and art together is a good model for science club education. In the following part, a **Chemistry and Art science club** (the so called StarT science club) is described as an inspiring model. Its operations are a part of design-based research, in which it is researched how integrating science and art and club operations, support children's interest towards chemistry. At least a thesis is on the way on the topic, as well as a scientific publication.

Figure 39. In the *Chemistry and Art* science club, the solubility phenomenon was studied by using permanent markers with different liquids. At the same time, the children were able to produce gorgeous dyed fabrics that the children could take home with them. (Picture: Essi Purhonen)

A StarT science club that integrates chemistry and art was carried out for 3rd to 7th graders and it was organized in the LUMA lab, ChemistryLab Gadolin. It was one of the clubs that was organized in cooperation between the Finnish Union of University Professors and LUMA Centre Finland for Finland's Centenary. Together with the eager members of the club, the professor mentors participated in exploring and wondering. In the Chemistry and Art science club, the mentors were the Head of the Department of Chemistry at the University of Helsinki, professor Heikki Tenhu and professor Maija Aksela, the Director of the Science Education Centre and the Director of LUMA Centre Finland.

Figure 40. The professor mentor, Heikki Tenhu, produced slime that is made up of polymers, with the children. It was inspiring to explore the behavior of polymers with the help of the slime. (Picture: Iisa Rautiainen)

In the club, interest was harnessed towards exploring phenomena in chemistry and everyday life; the development of research skills was at the heart of the operations. Here, the purpose was to bring chemistry closer to the children's own lives through relevant contexts. In the club, the children's own ideas were developed into **StarT projects**. Examples of project themes included chemistry in cosmetics and molecular gastronomy. Sustainable thinking is visible in the projects and it was one of the central themes. At the end of every club session, children were asked to

give feedback, and by doing this, they were able to influence the contents of future sessions and methods.

Families were invited to visit during the last club session, and they got to observe and experience the wonderful projects that their children had done. They got to make bioplastic, for example, with the guidance of the children. This turned out as an inspiring hands-on model.

Figure 41. The children got the chance to instruct their families on how to produce for example bioplastic during their Chemistry and Art science club. (Picture: Maija Aksela)

6.3 Models for Science Camps

Organizing science camps has been a part of the operations of science education at the University of Helsinki since 2004. These camps are organized especially during pupils' summer breaks (partly also during Autumn and Spring breaks). The camps are aimed at children and youth, who are interested in nature, science, the environment, mathematics or programming. In 2017, 31 summer camps were organized and there were more than 500 participating children and youth. The Science Education Centre not only organizes camps in Finnish, but also in Swedish and English, and the aim is to organize more international camps in the future.

The purpose of the camp is to inspire children and youth about natural sciences, mathematics, programming and other fields of science and to encourage them towards studying these subjects in the future. The aim is also to offer meaningful activities in the leisure time and to help children to get to know other children, who are interested in the nature.

Figure 42. Science camps are a subject of research of science education. They help children and youth to get inspired about science and help finding new friends. The summer camps also offer activities out in the nature. (Picture: Tuuli Holttinen)

The Science Education Centre has organized both camps that focus on a **specific field of science**, such as chemistry or math camps as well as theme camps that **integrate** various fields of science. Below you can find a few examples of inspiring camp models that have been organized before:

- **Android programming camp for 11–15 year-olds:** Programming for Android devices is practiced in the graphical online programming environment AppInventor. Participants get to make their own Android application, comprising of a few smaller games. They can continue developing the app at home after the camp. This camp is perfect for beginners and those who have used e.g. Scratch for programming. The camp employs established pair programming techniques but it is not necessary to have a partner before registering for the camp.

- **Looking for the missing jewel camp for 10–12 year-olds:** Someone has broken into Mrs. Von Banneker's apartment and her precious jewel has gone missing. The participants of the camp work as detectives and figure out what has happened to the jewel. Is there an individual behind all this or could this be the work of an organized crime group with extremely developed methods?

Where do the clues lead to and is it possible to find the missing jewel? How is her son, who just moved to England, connected to all this? The purpose of the camp is to explore mathematics and computer science through role play and solving problems. Do the children have the courage to take up the challenge and step into the shoes of a detective?

- **Science theater in Kumpula camp for 9–12 year-olds:** Are you amazed at the fantastic science show performances? Are you pondering on the science behind magic tricks? Are you a performer, who would like to model inspiring natural science phenomena through theater? If you thought of answering yes to any of the questions, then this science camp is the perfect camp for you! In the camp, we plan and carry out either a fantastic science show or a breathtaking theater performance, together. The outcome is up to you! It is certain that you will get to know the interesting world of acting and to learn about mind-shocking phenomena in science.

- **Dealing with physics camps for 8–10 year-olds and 10–12 year-olds:** In this camp, you will get to know the wondrous world of physics through experiments and demonstrations. At the camp, it can be observed what happens to marshmallows in a vacuum, how are the sound effects in movies made, how does a water rocket fly and how do we fool time.

Research and development work is a part of science camps: in the camps, new solutions and pedagogical innovations are developed for an inspiring science education. The relevance of science camps has been researched in a Master's Thesis.[135] [136] Research data was collected on children's understanding of scientists, in the summer camps in 2017. Now a thesis is going to be written and a scientific publication is going to be made concerning the research data.

According to the research on science camps, the children and youth that participated on the camps thought that the following things motivated them: (i) getting new friends, (ii) various and interesting activities such as laboratory work, microscopy, game programming and mathematical brain teasers, (iii) they learned things that are useful for them in the future, (iv) they received useful information on scientific career opportunities and on questions concerning choice of a profession and (v) they want to have an effect on the well-being of the earth and society in the future.

135 Halonen, J. (2017). Non-formaali tiedekasvatus: Tiedeleirien relevanssi lasten ja perheiden näkökulmasta. Pro gradu -tutkielma. Helsinki: Helsingin yliopisto. http://urn.fi/URN:NBN:fi-fe2017112251808

136 Halonen, J. & Aksela, M. (2018, accepted). Non-formal Science Education: The Relevance of Science Camps According to Children and Families. *LUMAT, 6*(1).

6.4 Models for Science Parties

Science parties are an area of research and development of science education of the Centre. It is an operating model that inspires children, youth and families towards learning about science and having science as a hobby, according to experiences. Science birthdays have been organized since 2012 by science education at the University of Helsinki. The first birthdays were organized in the ChemistryLab Gadolin in 2012.

Since 2017, new science party entities have been developed for both natural science and math birthdays. New science party packages are based on various themes that include different demonstrations and experiments, where the most interesting ones can be chosen.

New packages are meant for all ages, and these are not limited to birthdays. They have been developed on the basis of newest research information as a part of teacher education. It is possible to organize other events in science labs, not only birthdays, such as science themed recreation days or Christmas parties for companies.

The Science Education Centre organizes science parties for example with the following themes:

- Tasty molecules: At the birthday party, you will get to explore the secrets of molecular gastronomy and prepare ice cream or sorbet yourself.
- Escape room: Make your way out of an escape room full of mysteries by using team work and natural sciences.
- Detective: At the birthday party, you will get to be a detective and solve secret writings with the help of chemistry.
- Colorful chemistry: It's all about color in these birthdays. We conduct various inquiry and demonstrations, in which colors play an important role.
- The Amazing Race of Math: Go on an adventure around the Kumpula campus and solve exercises just like in the Amazing Race! Team work and having fun are crucial in this mathematical orienteering activity. The answers can be documented either by taking videos or pictures.

6.5 Virtual Operating Models

The development of virtual science education on the basis of research has been one of the areas of development since 2003. The purpose is to give joy of insight and success for all children and families. Operating models for virtual science education have been: (i) **Ksenonit virtual club** (started its operations in 2003), (ii) **Jippo online magazine** for children (started operating in 2008), (iii) **small**

children and families' Jippo virtual club (started operating in 2014–15; this has been described in the small children's science club -section), (iv) **Linkki virtual programming club** (launched in 2015–16) and (v) **StarT GoEdu! science club** (started its operations in 2017).

The virtual club **Ksenonit** (**Xenons**) is meant for children under school age and children in primary school as well as their parents and teachers. The **website for Ksenonit** was opened in the Fall of 2003. Instructions were published on the website, so that parents would be able to carry out inquiry-based work at home (see also chapter 6.2). Because of its popularity, it was renewed into a **Jippo online magazine** in 2008 that was updated on a regular basis. New activities, brain teasers, competitions, a Christmas calendar and news were published in Jippo. The children participated in the making of the magazine by reporting on their own research, by sending their writings to be published and by asking their own questions in the "Ask from Jippo" column. Class teachers were encouraged to produce new contents for the Jippo magazine with their classes. A virtual club was opened as a part of the online magazine in 2014 that was connected to the research and development project of small children's science education. In the virtual club, the children with their parents were encouraged with the help of short, inspiring videos to carry out functional/inquiry-based research for example at home, in a club or at kindergarten. It was possible for children, supported by their parents, to report their own research in the club website in the form of pictures of videos. The Jippo online magazine including the virtual club have been archived online since 2016[137].

Figure 43. **Jippo online magazine** that inspired children and families. It received the annual state award for information publication in 2009. Inspiring small children's science education website[138] continued the operations of the archived Jippo online magazine in 2017.

137 http://jippo.myscience.fi/

138 http://blogs.helsinki.fi/pikku-jipot/

The purpose of the **virtual *StarT GoEdu!* science club** is to inspire children and youth into observing their surrounding environment and to conduct their own research. The club also supports participating in StarT program by offering ideas for carrying out project-based learning. The virtual club is aimed at 3rd to 7th graders, but it offers things also to other ages. The club has been organized both in Finnish and in English.

Figure 44. It was pondered in the **StarT virtual club**: What kinds of feelings do astronauts go through while they are traveling through space? (Picture: Amanda Lehtola)

The themes for the **StarT GoEdu! club** have been chosen from StarT's themes, such as mathematics around us, nature and the environment, and technology around us. The following activities have been done in the club: building models of buildings and statues, learning about what goes in a trash can and thinking about how can trash be reused, and programming of own games. Videos have been published on the website of the virtual club,[139] the videos help in guiding research. In each of the videos, the theme is shortly introduced, and ideas and instructions are given for carrying out individual projects. Participants can choose the extent of their project individually and they are encouraged to participate in StarT with their club projects. Research is a part of developing the virtual club.

Linkki virtual programming club has offered weekly programming challenges in the graphical Scratch programming environment. These challenges can for instance be built around different events in the calendar year. In 2015 and

139 http://start.luma.fi/en/start-goedu-virtual-science-club/

2016 the club also offered a Christmas calendar of daily challenges, games and projects. The development of these kinds of lighter programming challenges has in turn helped in the development of teaching materials in computer sciences in the form of bringing in fresh ideas. The materials developed have then been offered freely online and have been used in programming education in schools and clubs all over Finland. It is important that virtual and online projects are not seen as a separate task, but instead are considered an intrinsic part of the activities offered to the children and youth locally.

6.6 Events for Families

The development of various family operating models has been and will be the subject of research and development in science education. Since 2003, various functioning models have been developed in science education: (i) **Ksenonit science days**, (ii) **Jippo science days**, (iii) a **ThinkFest event in cooperation** with the administration of the university, (iv) **science parties** and (v) **different family clubs** (the inquiry-based homework and the virtual club model) or (vi) family members participate in some of the operations or at the end of the sessions.

Families have always been interested in supporting their children's science hobbies. Especially, there is a need for such operations, where children get to try things in practice in a safe way by themselves, with their parents, grandparents or godparent(s).

Various science days have been a significant operating form of science education. Originally science days were built of functional workshops from different fields of science and there were also lectures, where researchers might have been dressed up as characters (e.g. Pippi Longstocking or Hemulen from the Moomins). **The Ksenonit science day** got its name from the virtual website Ksenonit, that was later known as **Jippo**. Here, the families together carried out inquiry-based work and functional exercises that were produced by the teacher students. It was a part of pre-service teacher education, at the same time.

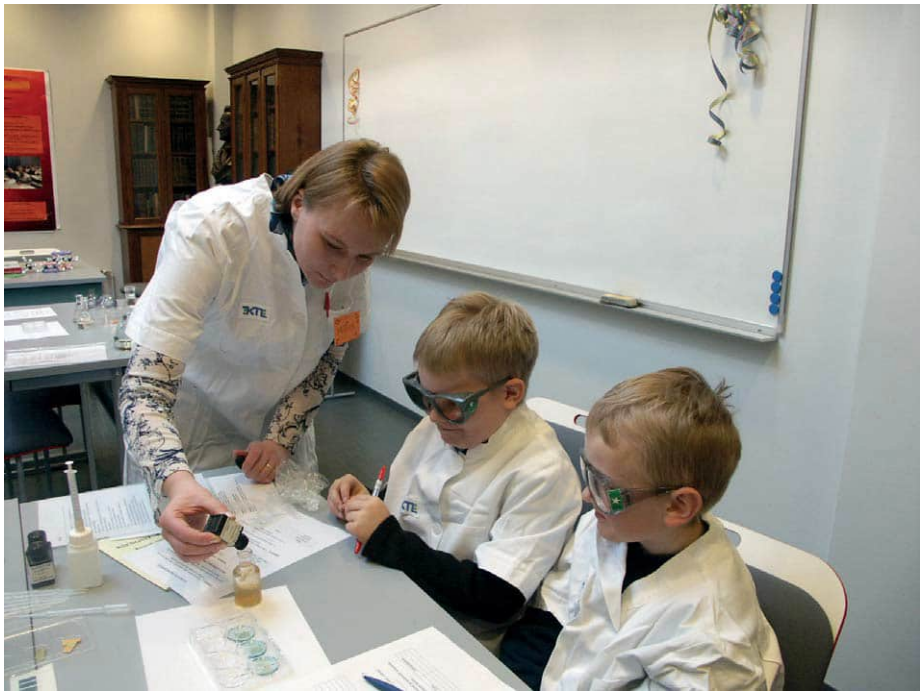

Figure 45. A chemistry workshop in the Ksenonit science day in Kumpula in 2004. It was carried out as a part of pre-service teacher education at the Department of Chemistry (Picture: Lauri Vihma)

Nowadays, a family day is organized as a part of a popular event at the university, the ThinkFest event. In 2017, around 900 family members participated in it, and it was organized by science education on the Kumpula campus. In addition, along the years we have been actively participating in organizing the events in the Night of Science festival, and Night of Science events in the Science Centre Heureka. New inquiry-based activities (that have been subjects of development) have been tested in these events.

7. NEW APPROACHES IN SCIENCE EDUCATION FOR YOUTH

This chapter introduces a few inspiring models for youths' science education (both physical and virtual) as research and development environments. Their purpose is to encourage youth towards different fields of sciences according to the aims of the Science Education Centre (see Foreword).

7.1 Operating Models

In order to develop meaningful science education for youth, numerous different operating models (see Figure 46) in research and development projects have been used:

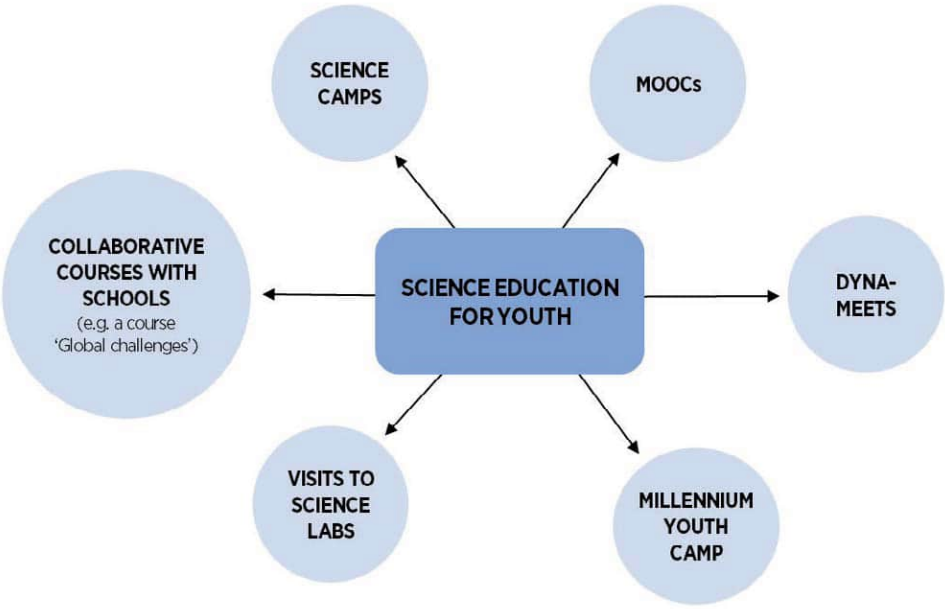

Figure 46. The forms of science education aimed at youth. They operate as research and development environments of science education as well as learning environments for teacher training.

7.2 Models for Science Clubs

The following two operating models are described: (i) ***SoMa club* for girls** and (ii) **a virtual *Mathversum* club**.

Encouraging girls towards LUMA subjects has been a focus area of science education. In 2013, Summamutikka organized a math club for the first time that was aimed only for girls. Applied mathematics for girls, **the SoMa club**. The purpose of this club was to inspire girls towards math and to show that the field of mathematics has a lot of interesting studying and career possibilities to offer. In the club, the participants got to explore recent research occurring in mathematics, through hands-on activities. Female mathematicians also visited the club and they acted as role models for the participants of the club. The club activities were planned in cooperation with mathematicians and statisticians and they were based on the topics of top research of researchers' own fields of science.

Figure 47. What kind of a tumor is there inside this infected box? The participants of **the SoMa club** got to explore medical imagining with the help of a Mystery box exercise. (Picture: Elisa Lautala)

The SoMa club was organized for a second time in 2014, after which the operations were extended, because encouraging youth into mathematics was seen as extremely important.

The web was chosen to be used to spread the operations and this is how a new virtual math club **Mathversum**[140] was produced. Because the operations were moved online, it was decided that the club would be offered to both girls and boys. Four club entities have been published on the website of the virtual club, where mathematics and art are being explored and information is given on what different specialists in various fields need math for. Each club video contains a short introduction on the topic as well as instructions for carrying out hands-on research individually. The virtual club materials have been used as a part of school operations. A part of the teachers have used these materials in class, when a part of them have organized physical clubs based on the virtual club. The virtual club has been developed as a part of research concerning a Master's Thesis[141] [142].

7.3 Science Camp Models – National and International

In this chapter, two good implementation models have been described: (i) The Science Education Centre's summer camps **for the youth** (chapter 7.3.1) and (ii) a model for supporting the interests of high-achieving youth, and networking internationally: **Millennium Youth Camps.** These both have been a part of research and development **of the Centre.** A dissertation has been written from the latter model, and six international scientific publications have been published.

7.3.1 The Science Education Centre's Summer Camps for the Youth

Since the beginning of the science education operations at the University of Helsinki in 2003, science-themed summer camps have been organized for children as well as for youth. The first summer camp that was organized for the youth was the popular ***Me, a chemist?*** camp for upper secondary school students. During the camp, the youth were instructed by chemistry teacher students and they were able to observe the operations of the department and to conduct their own research in an authentic research environment. Its purpose is to inspire youth towards chemistry and to present various career possibilities among natural sciences. More people applied to this camp than there were places.

140 http://blogs.helsinki.fi/mathversum/

141 Karjalainen, E. (2017). Kehittämistutkimus: Virtuaalinen matematiikkakerho. Helsinki: Helsingin yliopisto. https://helda.helsinki.fi/handle/10138/224587

142 Räsänen, J. J., & Karjalainen, E. (2016). Matikkaa virtuaalikerhossa. *Dimensio, 80*(2), 29–31.

Figure 48. Young researchers on *Me, a chemist?* camp in 2003. (Picture: Lauri Vihma)

In 2016, camps for youth were relaunched, and in 2017 the camp Me, a chemist? was turned into a interdisciplinary Me, a scientist? camp.

- **Me, a chemist? summer research courses for upper secondary school students during 2003–08 and 2016:** the students got to explore research in chemistry and they carried out their own research in an authentic research environment at the University.

- **Me, a scientist? camp for 14–19 year-olds in 2017:** the students explored research in Chemistry and Physics at the Kumpula campus. The camp days consisted of visits to research departments, project-based work and workshops on science. The camp is aimed at youth interested in science.

Linkki Science Lab has organized a special **programming camp for girls** during several summers, covering themes such as programming a virtual pet for an Android device. In modern society, computer science, programming and computer skills are thought of as things that mostly interest men. When compared to boys, girls tend to adopt more negative attitudes towards and beliefs about their own competences, regardless of their actual skill levels. The only really special thing about these camps has been that they were specifically advertised as girls-only. We have also made sure

that at least a part of the instructors are female. We will continue these targeted group activities in the future, also incorporating visits with female researchers in the field. It has been found that this kind of targeted intervention has the effect of improving girls' attitudes. Their attitudes were measured before and after the camp, and it was found out that their more negative preconceptions were improved during the camp, achieving similar self-efficacy levels as boys had after a similar camp[143].

7.3.2 A Model for Supporting the Interests of High-achieving Youth, and Networking Internationally: Millennium Youth Camps

As a subject of research and development in science education, an international camp for high-achieving youth was planned and organized in cooperation with different cooperation partners. **The international *Millennium Youth Camp*** was organized in Finland during 2010–14 for the high-achieving youth all over the world, in cooperation with Technology Academy of Finland (TAF) and later on with Aalto University. Nearly 20 companies participated as sponsors and cooperation partners. Top researchers at the university and in companies, university students, including teacher students from the University of Helsinki participated in the implementation of the camp.

The idea of this internationally unique science camp was to increase the youths' interest towards natural sciences and technology and to tell about Finnish skills and innovations as well as study – and career opportunities in Finland.

Participants (30, later 60) were chosen to the camps from 1000 ... 2000 applicants through a selection process that had two or three stages. At its best, there were participants from 30 countries. The chosen participants were divided into teams according to the theme they had chosen. The themes were e.g. biosciences and technology, energy, ICT and digitalization, food sciences and -technology, climate and climate change, materials science and -technology, applied mathematics, renewable resources, water and urban planning. The youth visited Finnish companies and universities in the Helsinki Metropolitan Area. During the camp, the participants produced a project work of their theme with their teams, while being instructed by specialists from the university and specialists in the private sector. At the end of the camp, they presented their project works in a formal Millennium Youth Camp gala. Diplomats from various countries of the participants took part in the gala.

Figure 49 (on the next page). An inspiring international Millennium Youth Camp was one research and development project of science education in cooperation with various cooperation partners. Numerous scientific publications and a dissertation have been written on the topic. (Pictures: University of Helsinki's Science Education)

143 Hjelm, E. (2016) Tytöt, pojat ja tietojenkäsittelyn opettaminen. Pro gradu. Helsingin yliopisto. https://helda.helsinki.fi/handle/10138/162056


Carioca

The Science Education Centre brainstormed the camp with the partners, coordinated the selection process of participants, chose and trained the personnel of the camp and planned and carried out the program of the camp, including an 'Amazing Race of Science' competition on the Kumpula campus. The youth that participated in the camp made new acquaintances and lifelong friendships with each other and with the specialists in the private sector and Finnish academics on the field. Around a dozen participants have accepted the study place that they were offered at the Faculty of Science at the University of Helsinki.

A doctoral dissertation[144] concerning the research-based development of the camp has been written and a couple of scientific publications.

7.4 Course Models for Upper Secondary School Students

Since 2003, upper secondary school groups have been welcome to visit the university as a part of their course. For example, numerous student groups have conducted inquiry-based laboratory work at the university under the instruction of university teachers. In the following part, **three good course models** that have been carried out during last years, are presented. They are a part of research and development operations of science education.

7.4.1 An Intensive Course on Pharmaceutical Chemistry

This course on pharmaceutical chemistry includes lectures from specialist in chemistry on e.g. drug delivery vehicles, radiopharmaceuticals and IR-, MS-, and NMR- analysis methods. After the lectures, the students get to use the information that they have just learned, and they complete a hands-on inquiry-based work, a mystery on pharmaceuticals in LUMA lab, ChemistryLab Gadolin.

The course has been carried out since the Spring of 2016 in cooperation with Etelä-Tapiolan lukio (an upper secondary school in Espoo) and with Olarin lukio (an upper secondary school in Espoo). (the course is a part of teaching in these upper secondary schools). The cooperation continues in the Spring.

144 Tolppanen, S. P. (2015). Creating a Better World: Questions, Actions and Expectations of International Youth on Sustainble Development and its Education. Helsinki: University of Helsinki. http://urn.fi/URN:ISBN:978-951-51-1312-2

7.4.2 A Course "Chemistry of Health and Well-being"

The aim of the course is to extend the students' understanding of the significance of chemistry on the fields of well-being and health, and to encourage students towards studying chemistry.

Figure 50. At the final lecture of a course "**Chemistry of health and well-being**", the students presented their project works that they had done during the course, to each other and the personnel of the University of Helsinki. (Picture: Johannes Pernaa)

Central in the contents of the course are: lectures from specialists, inquiry-based work in the laboratory and completing StarT projects. The eight speakers that were chosen, work in promoting health and well-being and especially the chemistry connected to these. Seven of them were researchers on fields of chemistry and pharmacy. During the course, there were lectures on e.g. drug ingredients that could be gotten from potential sea organisms, the opportunities of using nanofibres and -coating on bone grafts/implants and in supporting structures of bones, as well as the opportunities of respiration analytics in the diagnosis of various illnesses. In addition to the academic research lectures, there was also a lecture by a specialist form Orion on what specialists in chemistry may end up doing in companies in the fields of well-being and health.

In addition to the specialist lectures, the participants of the course got to learn more about the topic through laboratory work. The students implemented and planned brief chemical researches on health and well-being in small groups. They were presented at the final session of the course. The students could choose the themes for their projects and could also participate in StarT operations with their

projects. During the course, all the students produced their own medical lotions in a laboratory, as a part of a Master's Thesis.

During the course, the students wrote down their thoughts on the themes of the course in the form of a learning diary. These texts and the course as an entity were used as data for another Master's Thesis. Future teacher students from the course "**Chemistry as a science**" that was in operation in the Fall, also came to listen to the lectures of the course in order to collect data from other upper secondary school students for their own research projects. The science education of chemistry and its research and chemistry teacher's basic education were integrated in the course.

The pilot course was carried out in cooperation with the Ressu upper secondary school. 17 upper secondary school students took part in the course. The entire course received very positive feedback from students and the purpose was to continue the cooperation. The course is going to be made into an online course for all upper secondary school students.

7.4.3 A Course 'Global Challenges'

The course 'Global challenges' has been developed for upper secondary school students in cooperation with upper secondary schools in Espoo. The course has been described in chapter 5.2.4. It is a part of new teacher training.

7.5 Dyna-meets

Clubs that focused on specific fields of science were previously organized in the Centre for youth in the lower/upper secondary level (e.g. F2k and Gadolin clubs). In the club meetings, science-oriented youth are able to get to know sciences through "fun facts", workshops and visits, they also got to know the newest innovations as well as specialists of universities and other communities and their work.

In 2013 all the separate clubs were united into one **Dyna-meets** concept. Free meetings, "meets" were organized in the Helsinki region on university campuses, research institutes or in companies. In "meets" the specialists presented research methods and equipment, and they told about the new winds of their research, their work and study opportunities on their field. In "meets" during a term, there was an interdisciplinary theme, for example crime investigation. The youth were able to get a **LUMA diploma** if they participated actively on the "meets" and if they reported on the meetings. The students, who received a LUMA diploma had the chance of asking the rector of their upper secondary school to count the participation in the "meets" as a course in upper secondary school.

Figure 51. In the **Dyna-meets**, using hydrogen energy as the source of energy for cars is researched. (Picture: Sakari Tolppanen)

Nowadays, this model has been developed into a mutual concept[145] in the LUMA Centre Finland network, where youth are encouraged to participate in public events that are organized by universities and vocational schools on the themes of natural sciences, mathematics and technology. They are also expected to report on these visits in the form of learning diaries. By reporting on their participation, the youth have a possibility of receiving a LUMA diploma.

7.6 Virtual Operating Models

Virtual operating models of science education also for youth are developed on the basis of research at the Science Education Centre. In the following part, a couple of examples are presented. An international online course for youth has been described in chapter 3.3.4

145 http://www.luma.fi/dyna-miitit/

7.6.1 National and International Online Publications for Youth

The scientific online magazine for the youth, ***Luova* (My Science)** was established according to the model of the Ksenonit/Jippo magazine in 2008. The magazine aimed at being a developing and interesting meeting place for researchers, teachers and the youth – the source that supports youth's own activeness and interests, through which youth are able to interact and spread their interests to each other. The articles for the magazine were written mainly by students studying to be teachers. Some youths, in the lower/upper secondary level, also volunteered to write articles and others wrote articles as a part of their familiarization with working life practice at the Science Education Centre.

The main purpose of the magazine is to give the opportunity for youth to participate in science, research and innovations connected to the joy of finding, invention and creativity. The magazine received the state award for information publication in 2009. At the beginning, the magazine was read by thousands of people per year. Youth's interest online focused more on video narration and therefore since the summer of 2016, the magazine has been archived.[146] Virtual clubs for youth that are based on videos, such as ***Mathversum*** (see chapter 7.2.) are a better way to activate the youth.

Figure 52. The popular **Luova** (MyScience) online magazine for youth.

146 http://luova.myscience.fi/

The sister magazine of Luova, is the ***Kreativ*** magazine in Swedish and it was published in 2008. The magazine was archived[147] in 2010, because there was no funding for the Swedish publishing operations.

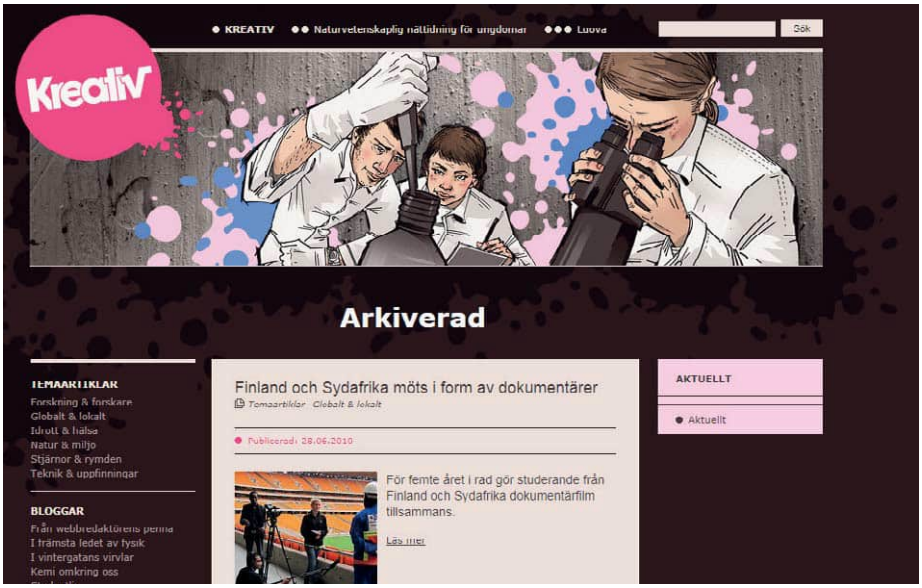

Figure 53. The popular Kreativ online magazine for youth.

The international sister magazine of **Luova, *MyScience,*** was published since 2009. Originally, it was used for supporting operations of the Millennium Youth Camp. The purpose is similar to that of Luova, but internationally, and its special purpose is to bring forth the Finnish skills on the field and Finnish study -and career opportunities. In the first years, the magazine had tens of thousands of readers per year. Because of similar reasons as with Luova, the publishing of the magazine was ended in 2016. MyScience is archived online[148].

147 http://kreativ.myscience.fi/

148 http://myscience.fi/

Figure 54. The popular MyScience online magazine for youth.

In 2011, the Science Education Centre participated in organizing an event, *EU Contest for Young Scientists* (EUCYS), together with the Development Centre Opinkirjo. Connected to this, an online publication, ***European Journal for Young Scientists and Engineers*** **(EJYSE)**, was published, where 14–21 year-old youths could get their peer-reviewed research articles published. The Magazine was archived[149] in 2014.

Figure 55. EJYSE journal for youth.

149 http://myscience.fi/ejyse

7.6.2 Online Courses for Programming

High quality online courses for **programming** in Finnish (MOOCs)[150] have reached both teachers and students in primary school and lower and upper secondary schools. JavaMOOCs that are offered by the University of Helsinki and that are based on the materials of the programming courses at the university have been organized in more than 60 institutions.

The MOOC model has two key strengths. First of all, it is very easy to organize a tailored local programming course: the university offers support with using the materials, solving programming exercises as well as evaluation, which allows the teacher to organize a course even if they have no programming experience prior to the course.

Another essential feature is the automatic analysis of programming exercises built into the course[151]. Automatic evaluation is primarily based on automated tests of the submitted programming tasks, making sure the programs work as instructed in the task, but it is also possible to include some structural analysis of the students' solutions.

In a cohesive learning environment it is also possible to automatically track the students' actions in order to model their progress and determine whether it is necessary to intervene and offer some additional guidance.[152] [153] [154] [155]

More in line with traditional teacher training, researchers of programming education from the University of Helsinki and Aalto University have participated in the development of the PythonMOOC component of the Koodiaapinen ("Code alphabet")[156] project. The course has been offered to teachers with the help of the Science Education Centre. PythonMOOC is aimed at teachers as a course that offers tools for the pedagogical aspects of teaching programming. Over 100 teachers have completed the course so far.

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150 http://mooc.fi/english.html

151 Arto Vihavainen, Thomas Vikberg, Matti Luukkainen, and Martin Pärtel. 2013. Scaffolding students' learning using test my code. In Proceedings of the 18th ACM conference on Innovation and technology in computer science education (ITiCSE '13). ACM, New York, NY, USA, 117–122. http://dx.doi.org/10.1145/2462476.2462501

152 Ihantola, P., Sorva, J. and Vihavainen, A. (2014). Automatically detectable indicators of programming assignment difficulty. In Proceedings of the 15th Annual Conference on Information technology education (SIGITE '14). ACM, New York, NY, USA, 33–38. http://dx.doi.org/10.1145/2656450.2656476

153 Ahadi, A., Lister, R., Haapala, H. and Vihavainen, A. (2015). Exploring Machine Learning Methods to Automatically Identify Students in Need of Assistance. In Proceedings of the eleventh annual International Conference on International Computing Education Research (ICER '15). ACM, New York, NY, USA, 121–130. http://dx.doi.org/10.1145/2787622.2787717

154 Ihantola, P., Vihavainen, A., Ahadi, A., Butler, M., Börstler, J., Edwards, S. H., Isohanni, E., Korhonen, A., Petersen, A., Rivers, K., Rubio, M., Sheard, J., Skupas, B., Spacco, J., Szabo, C. and Toll, D. (2015). Educational Data Mining and Learning Analytics in Programming: Literature Review and Case Studies. In Proceedings of the 2015 ITiCSE on Working Group Reports (ITICSE-WGR '15). ACM, New York, NY, USA, 41–63. http://dx.doi.org/10.1145/2858796.2858798

155 Heinonen, K., Hirvikoski, K., Luukkainen, M., & Vihavainen, A. (2014). Using CodeBrowser to Seek Differences Between Novice Programmers. *SIGCSE '14 Proceedings of the 45th ACM technical symposium on Computer science education*. New York: ACM, s. 229–234

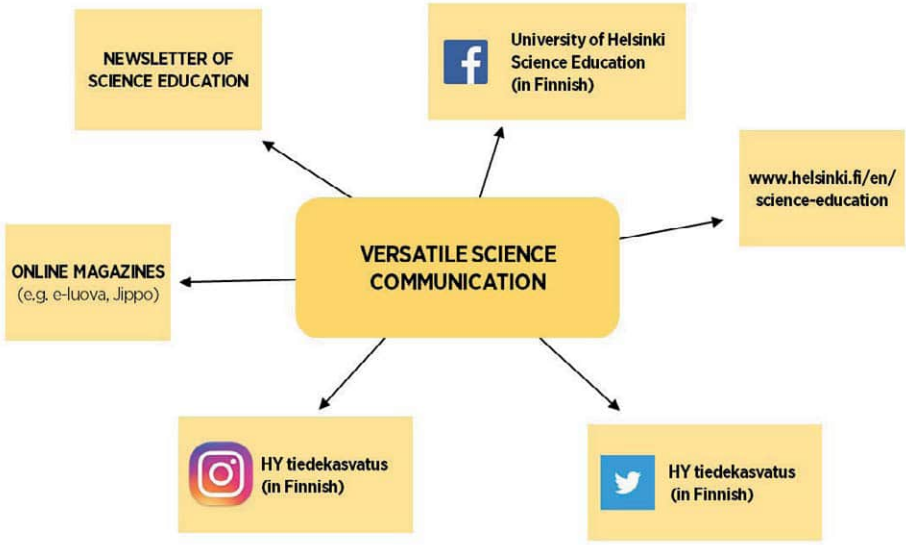
156 http://koodiaapinen.fi/en/

8. NEW FORMS OF COMMUNICATION

This chapter looks at what kinds of forms of good communication have been developed in the promotion of science education, according to the aims of the Science Education Centre. (see Foreword).

8.1 Communication Models

The Science Education Centre and its predecessors have from the beginning communicated openly and in a versatile way for different target groups.



Since the beginning, the website[157] and the newsletters that are transmitted via email (at first about once a month) have been an important route in communication. Developed data, information on research publications and theses as well as information on future offerings for children and entire families and teachers, are published on the website. The highlights of the season have been emphasized in the email newsletter.

157 http://www.helsinki.fi/en/science-education

Also, social media such as Facebook[158] and Twitter[159] have been used for quite a while. Recently, Instagram[160] has also been used. Some science labs also have their own profiles in social media.

In contact with the Centre, the responsibility of the editorship of the LUMA.fi online portal has been given to the national LUMA Centre Finland network, including the national LUMA News (in Finnish) part on current information as well as the international LUMA News part on current information.

Media announcements[161] have been published of the most meaningful new openings and events. Cooperation has occurred also with radio -and television programs.

8.2 LUMAT Online Publications: National and International Open Route for Publishing Peer-reviewed Research and Spreading Out Pedagogical Innovations

The LUMAT journal was established in 2013 for a publishing route of research information in both Finnish and in Swedish, there was an acute need for such a route. In addition to publishing in Finnish and in Swedish, the LUMAT has published manuscripts also in English since the beginning. The publication has been given over to the LUMA Centre Finland network, but the editing happens in practice in connection with the Science Education Centre at the University of Helsinki. The magazine has an international scientific board.

In 2016, LUMAT was divided into part A and part B. The purpose of this was to clarify the publishing class of the articles to the reader and at the same time develop the evaluation process. During the years, LUMAT has evolved and become more international. Nowadays, LUMAT publishes research from around the world.

The LUMAT consists of two journals: LUMAT[162] and LUMAT-B[163]. Both of these journals publish research articles from the research fields of math, science and technology education, but from slightly different viewpoints. LUMAT publishes only peer-reviewed research articles, whereas LUMAT-B focuses on publishing article entities of conferences, symposiums, seminars and projects.

158 https://www.facebook.com/HelsinkiUniversityScienceEducation/

159 https://twitter.com/tiedekasvatus

160 https://www.instagram.com/tiedekasvatus

161 https://www.helsinki.fi/fi/tiedekasvatus/ajankohtaista/mediatiedotteet

162 https://www.lumat.fi/index.php/lumat

163 https://www.lumat.fi/index.php/lumat-b

APPENDICES

Appendix 1. The Working Group for the Book

The writing of the book has been a great, communal process, according to the motto of science education operations: "**Together we are more!**".

The editors of the book have participated in writing the book (**Maija Aksela, Juha Oikkonen** and **Julia Halonen**), as well as members of the steering group

- **Ismo Koponen**, Department of Physics (F2k science lab)
- **Lea Kutvonen**, Department of Computer Science (Linkki science lab),
- **Rami Ratvio**, Department of Geography (Geopiste science lab),
- **Anna Uitto**, Department of Education (Luma ambassadors project) and
- **Marjo Vesalainen**, Centre for University Teaching and Learning (science education in humanistic subjects).

and previous/present coordinators of the Centre (**they have participated in writing about science education on their fields**)

- **Pipsa Blomgren** (science education in chemistry),
- **Tuuli Holttinen** (science education in humanistic subjects),
- **Markus Jylhä** (science education in geography and geosciences),
- **Merike Kesler** (science education in kindergarten -and class teacher training),
- **Helena Laasjärvi** (science education in biological and environmental sciences),
- **Laura Lahti** (science education in humanistic subjects),
- **Tapio Rasa** (science education in physics),
- **Jenni Räsänen** (science education in math and statistics) and
- **Virpi Sumu** (science education in computer science)

as well as specialists that have operated in different projects of science education (they have participated in writing the parts of the text that are mentioned inside parentheses)

- **Outi Haatainen** (StarT operating model, Everyday chemistry project, Luova project)
- **Jaana Herranen** (the ActSHEN project, A good question! project)
- **Maya Kaul** (Research Assistant, proofreading)

- **Päivi Kousa** (the COMBLAB project and Science and mathematics in society: interdisciplinary cooperation with companies project)
- **Saara Lehto** (the LUMA FINLAND development program)
- **Meri Mikkola**, Research Assistant, University of Helsinki (translation from Finnish to English)
- **Johannes Pernaa** (Computer assisted molecular modelling in school teaching project, International LUMATscientific publication)
- **Essi Purhonen** (the International StarT operating model, Chemistry and art science club, StarT virtual club)
- **Iisa Rautiainen** (Chemistry of health and well-being project, Chemistry and art science club)
- **Maiju Tuomisto** (Formative assessment in science education project and Molecular gastronomy in LUMA education project)
- **Jaakko Turkka** (the Designstem project, StarT virtual club)
- **Lauri Vihma** (e.g. administrative things)

Appendix 2. Central Operators of the Science Education Centre

Since 2003, over 100 people have been a part of the operations of the Science Education Centre as well as its preceding centres. Information on the central operators of the LUMA Centre can be found from previous annual reports[164]. Lecturer **Marja K. Martikainen** was the coordinator of AinO Centre at the beginning, and previously Senior Lecturer **Marjo Vesalainen**.

Since 2017, the Director of the Science Education Centre has been Prof., PhD **Maija Aksela**, who has been a part of the operations since 2003, and the Coordinator has been M.Sc. **Julia Halonen**.

The Executive Board of the Science Education Centre in 2017–2020

The Dean of the Faculty of Science appoints the Centre's executive board for a term and acts as the President for the executive board. In a negotiation with the Rector in the Fall of 2016, it has been agreed that the Faculty of Science acts as a responsibility unit for the Science Education Centre. The current executive board has been appointed for the term of 1.1.2017–31.12.2020. The assembly of the executive board is reviewed, because of an internal structural change at the University since the beginning of 2018. Since the beginning of 2018, the Dean of the Faculty of Science is Prof. **Paula Eerola**.

164 https://www.helsinki.fi/fi/tiedekasvatus/keskus/toimintakertomukset

The purpose of the Centre's executive board is to

1) decide on strategic alignments, on the possible re-organization of the operations and on long-lasting cooperation contracts
2) approve a long-term plan of action concerning the term, approve the budget and the annual plan of action and budget, and
3) verify the annual report

The director of the Centre proposes the resolutions to the executive board.

The Steering Group of the Science Education Centre in 2017–2020

The Centre's steering group supports the directing of the Centre and the planning of the operations. The steering group consists of specialists from different units at the University of Helsinki and of representatives of cooperation partners that operate outside the university. The members that represent the university community, work in the Centre's practical research and development operations. The assembly of the steering group[165] can be altered flexibly.

The Personnel of the Science Education Centre at the Beginning of 2018

(email address: first name.last name@helsinki.fi)

PhD, Prof.	**Maija Aksela**	director
B.Sc.	**Pipsa Blomgren**	coordinator of science education in chemistry
M.Sc.	**Julia Halonen**	general coordinator
M.Sc.	**Markus Jylhä**	coordinator of science education in geography
M.Sc.	**Merike Kesle**r	coordinator of science education in kindergarten -and class teacher training
B.Sc.	**Helena Laasjärvi**	coordinator of science education in biology
PhD	**Laura Lahti**	coordinator of science education in humanistic subjects
PhD, Prof.	**Juha Oikkonen**	vice director
M.Sc.	**Tapio Rasa**	coordinator of science education in physics
M.Sc.	**Jenni Räsänen**	coordinator of science education in mathematics
B.Sc.	**Virpi Sumu**	coordinator of science education in computer science

The University Services' various fields of operation support the operations of the Centre.

165 https://www.helsinki.fi/en/science-education/centre/leadership-and-decision-making

Appendix 3. The Sponsors of the Operations of the Science Education Centre, and Cooperation Partners

The University of Helsinki has sponsored the Centre's operations yearly. For separate research and development projects as well as training programs, funding has been received from numerous foundations and companies. Funding for the projects in the LUMA FINLAND development program has been received from the Ministry of Education and Culture. For teacher's in-service trainings, funding has been received from the Finnish National Agency for Education. More specific information can be found from previous annual reports[166].

In order to attest the funding of the research-based development of new innovations, a Science Education Fund has been opened[167].

166 https://www.helsinki.fi/fi/tiedekasvatus/keskus/toimintakertomukset

167 https://www.helsinki.fi/fi/tiedekasvatus/keskus/lahjoita-tiedekasvatusrahastoon

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