Vahur Mägi*

From the 17th century to the present-day in Estonia: Evolution of exact and natural sciences

(1) Introduction

All scientific literature published in Estonia in the past is either in Latin or German written by authors coming from abroad, mostly from Germany. The original creative thought in the literature is usually lacking and, therefore, it is insignificant in the general history of science. Yet, it is interesting — first and foremost, from the standpoint of observing the spread of scientific ideas since the literature played the key role in West European scientific thought reaching the Baltic countries. At the same time, it is a significant source from the aspect of the Estonian education history providing knowledge for the compilers of the first writings and textbooks on popular education in the Estonian language. The first secondary schools in Estonia, then a province of Sweden, were established in Tartu (1630) and Tallinn (1631). The secondary school in Tartu was granted the rights of a university in 1632 and renamed *Academia Gustaviana*.

(2) Through fortification to mathematics

The schools were also required to teach mathematical disciplines. Their professors wrote the first books published in Estonia containing mathematical knowledge; the very first was "*Florilegium fortificatorium tripartitum*"(1647) by Gebhard Himsel, professor of mathematics at the secondary school in Tallinn. In his book, the author addressed the issues of fortification — planning towns and constructions, depicting perspective, the rules of military architecture and their application in fortification. Since this was closely related with mathematics, Himsel even considered fortification a part of mathematics. The book begins with the basics of geometry and finishes with those of trigonometry. Also the next book published in Estonia containing practical knowledge of mathematics — "*Anfang der Attaquen*" by Julius Woltemate (1682) — was a textbook on fortification. While in the books by Himsel and Woltemate mathematics had a supporting function, J. Schelen, professor of mathematics at *Academia Gustaviana*, set himself a different objective — he published his four-volume "*Cursus mathematici*" in Tallinn in 1665. At the time, it was a respectable publication providing a thorough overview of geometry, arithmetic and geodesy etc. The part on geometry was based on the theories of Euclid. Earlier, J. Schelen had published in Tartu a book on calculation by means of Napier's bones. His productive work in mathematics was continued a few decades later by Sven Dimberg, professor of mathematics at *Academia Gustavo-Carolina*. He supervised writing of several dissertations a number of which dealt with mathematics. Dimberg was aware of the radical changes in natural sciences in the 17th century, especially of the works by I. Newton. One of the dissertations addressed Newton's theory of light, another O. Guericke's experiments with Magdeburg hemispheres. Dimberg was also interested in Newton's works on mathematics. During the academic year of 1698–1699, he did a course on Newton's basic principles of higher mathematics — the first known case where elements of higher mathematics were taught in Estonia. In addition to teaching mathematical disciplines, the professor of mathematics was also responsible for teaching astronomy, geography, geodesy and architecture. Geography was taught together with mathematics because of the applied aspects of geography such as geodesy and cartography. Dimberg had plans to open a chemistry laboratory and an observatory in Tartu but the Great Northern War thwarted his plans.

* Tallinn University of Technology, Talinn, Estonia; email: Vahur.Magi@ttu.ee.

(3) Mathematical culture reaching everyday life

The influence of the above books on mathematics remained rather limited — people's knowledge did not improve — and no significant improvement in mathematical culture occurred in Estonia. The first book explaining terminology of mathematics in the Estonian language was published in 1795. Although it was a reader, it contained a chapter on numbers explaining numeration and the usage of zero as well as introducing the multiplication table. The reader by Georg Gottfried Marburg published in 1805 also contained chapters on mathematics. The University of Tartu education committee approved of Marburg's book and it was awarded a prize of the Livonian Public Welfare and Economic Society. The book "*Arropiddamise ehk Arwamisse-Kunst* " by Peter Hinrik Frey, principal of Kuressaare municipal school and later clergyman, can be considered the first Estonian textbook on mathematics. Within two decades following the publication of Frey's textbook, no books on mathematics were published in Estonian. In 1823, on the other hand, two works were published almost simultaneously: "*Arvamise-Ramat* " by Otto-Willem Masing and "*Arwo ehk Rehkendamise eksemplid* " by Abram Holter. The latter was a manual for school teachers. All authors of the above books begin by explaining numeration. Mostly Indian-Arabic numerals and the Hindu positional system were discussed. Marburg also introduced the Roman numeric system. The positional numeric system was described the best by Frey. Systems of measurement were another principal issue thoroughly discussed by all authors. The situation was, indeed, complicated. Different systems of measurement were used in Tallinn, Riga, Pärnu, Narva and Tartu, and for each substance, there was a separate system of measures.

(4) About mathematics in Tartu

In the 19th century, the University of Tartu became a centre of international importance in the field of differential geometry. Local scientists introduced significant applications in mechanics. Towards the end of the century, the mathematicians of Tartu attained distinction in celestial mechanics and mathematical methods for studying movements in near equilibrium systems. In 1922, the science room of mathematics was reorganised into the department of mathematics and mechanics in order to ensure better conditions for studies and research. The first textbooks on mathematics in Estonian were published for secondary schools and institutions of higher education. Those textbooks played an important role in formulating terminology of higher mathematics in the Estonian language. The first Estonian to receive a doctoral degree in mathematics was Hermann Jaakson (1926). He defended his dissertation, written in French in Paris on Fourier's method for solving infinite systems of equations, in Tartu. Edgar Krahn, whose original ways of thinking were highly appreciated by Richard Courant, became internationally known as a mathematician and a specialist in mechanics. Later Krahn worked in Germany, Great Britain and the United States. His research focussed primarily on aero- and hydrodynamics, and dynamics of elastic surfaces.

(5) Long way to understanding extragalactic star systems

Mauritius, principal of the Dominican convent school in Tallinn in the late 13th century, studied theology in Cologne and Paris. In Cologne, his teacher was St. Albertus Magnus who was familiar with the works of Ptolemy; therefore, it is reasonable to assume that the knowledge of Dominican monks about understanding the Aristotelian concept of a geocentric universe was at par with the knowledge available at the time. Notes of lectures on natural sciences — the so-called *Meditationes* — reached the area from France. The Town Council of Tallinn subsidised astronomy by paying for publication of calendars. Organists-assistants to pastors were paid to wind clocks. The Council facilitated development of astronomy also by promoting fortification since astronomy was considered to be within the competence of such specialists. The library of St. Olav's Church contributed to purchasing a telescope for G. Himsel (1673) whose research marks the beginning of optical astronomy studies in Estonia. The first institution to provide conditions for astronomy to develop consistently and establish an observatory was Tallinn secondary school. The school library contained a solid collection of books on astronomy as well as a celestial globe. The 18th century in Estonia was characterised by a high number of exact sciences related expeditions. In 1769, Poczobut, a Jesuit from Vilnius, and his assistant Strzeck studied the sky in Tallinn. Beside astronomic-geodetic expeditions, also gravimetric fieldwork was done. Topographic work was prompted by rapid development of cartography. Academic astronomy in the true sense of the word began in Estonia with the establishment of the observatory at the University

of Tartu. Friedrich Georg Wilhelm Struve did an astronomic-trigonometric survey of Livonia. Where possible, triangulation networks were established. Along the coast of the gulf of Riga, Struve had to establish the coordinates astronomically. The method applied has been described as a prototype of contemporary parallactic polygonometry. Struve became the principal authority in higher geodesy. When the military board of topography started to establish the length of a degree of longitude along the meridian on the area of Poland-Lithuania, Struve, based on his experience gained form doing surveys in Livonia, submitted a project to establish the length of a degree of longitude along the same meridian throughout the Baltic Sea provinces. Johann Heinrich Mädler studied binary stars. The amount of surveys he conducted with a Fraunhofer telescope is comparable with the surveys done by Struve. He calculated orbits of binary stars that enabled, based on Kepler's laws, determining the hypothetical distance of the binary stars from the Sun. Mädler's theoretical research in Tartu focussed on the structure and dynamics of the Milky Way. He can be regarded as the founder of contemporary stellar dynamics. He claimed that a balanced star system could exist due to it own gravity and did not need a massive central body. The tradition of research in star systems, including measuring binary stars, was maintained by Ernst Öpik who also turned out to be a pioneer of extra-galactic astronomy. Having been the first to reliably determine the distance of Andromeda Nebula, he, thus, proved the existence of extragalactic star systems. Principal research interests of Jaan Einasto are the structure and modelling of galaxies and galactic subsystems, and macrostructure of the Universe and modelling its evolution. He proved that majority of the matter in the Universe is dark and invisible forming massive crowns around galaxies. Einasto is the founder of the concept of the cellular structure of the Universe.

(6) Medical Students were first to study physics

In the early 19th century, the Chair of Theoretical and Experimental Physics was founded in the Faculty of Philosophy of the University of Tartu. Initially, lectures on physics were available only to medical students. The first professor of physics was Georg Friedrich Parrot, Rector of the University. He taught general physics and mechanics of solid bodies; special subjects were electricity, magnetism, galvanism, meteorology and physical geography. In 1803, he established the first science room of physics in Tartu. His articles were based on his own research and were mostly of applied science in nature. For example, he addressed topics such as lighting rooms, producing gunpowder, building ships' masts etc. His research made no significant contribution to science; only his chemical theory of galvanism is of some interest. His most outstanding achievement in methodology of teaching was a two-volume textbook on physics "*Grundriss d. theorethischen Physik von G. F. Parrot, 1809–1811*". Then meteorology occupied the leading position among the research interests of the physicists of Tartu. Friedrich Ludvig Kämtz studied law and linguistics at the University of Halle, afterwards devoting himself to physics and mathematics. In Tartu, he taught a general course in physics as the principal subject, and electricity, magnetism, the theory of light and thermology as special subjects. All his extracurricular free time was spent on research and summer vacations on travelling. Research in meteorology constitutes the most valuable part of his academic work. Moritz Hermann Jakobi, Professor of Civil Architecture at the University, became known for his experiments in physics. Apart from teaching, he studied electromagnetism and conducted experiments on galvanoplastic phenomena that lead to the discovery of galavanoplastics.

(7) The first textbooks on physics in Estonian language

When physics began to be taught at parish schools in Estonia in the middle of the 19th century, it created a practical need for teaching material on physics in the Estonian language. Johann Georg Schwartz published a physics textbook in 1855 that was the sixth book of his series of 8-volume schoolbooks published in 1852–1861. It is difficult to establish now whether it was an original textbook or compiled on the basis of a textbook in another language. It is, however, a valuable attempt to pass on knowledge of physics in Estonian. All the issues of school level physics were addressed in the book. Since no terminology existed, physical phenomena were described in popular language. The author of the physics textbook published next, Jakob Tülk, who had studied philosophy, mathematics, astronomy and chemistry in Geneva, Paris and Strasbourg, followed the lead of French and German textbook authors. Although, from the point of view of linguistics, the book was quite good, the material was difficult to follow and understanding it required extensive knowledge in mathematics.

The first extensive unification of terminology took place at the 1st congress of physics and mathematics teachers in Tartu in summer 1917.

(8) Gathering experience from world over

X-rays reached Estonia in 1896. Professor Aleksander Sadovski demonstrated the phenomenon at a public experiment in the physics science room in Tartu. Only a year later X-rays were used at the University Hospital to treat the patients injured in the serious railway accident in South Estonia. Research in X-ray structural analysis started a few decades later and is associated with the name of Professor Harald Perlitz. He got the idea to use X-rays to study the inner structure of substances during his trip to France in 1924 or perhaps in Riga where he went on a study trip as a student. During the following decade, H. Perlitz published articles on the issue. His preferred objects of research were inter-metallic compounds, especially silver and gold alloys. H. Perlitz presented generalized conclusions of his research in his doctoral dissertation in Tartu in 1932. Perlitz' trip to Stockholm, Oslo and Goettingen in 1930 had a significant influence on the development of X-ray structural analysis in Estonia. He co-operated productively with Professor A. Westgren and later sent V. Koern, one of his students, as a grant-aided student to him in Stockholm. Other students of Perlitz studied abroad: Albrecht Altma in Munich, Georg Mets in Leipzig and Hamburg, and Endel Aruja with a grant of the British Council at the Cavendish laboratory in Cambridge. Research in X-ray structural analysis laid the foundation to research in solid state physics that continue today. A number of Perlitz' colleagues went to work for Tallinn University of Technology and continued their research there. Johan Vilip, a well-known experimentalist and constructor whose principal research interests had to do with seismography, was invited to become the Professor of Experimental Physics. His most significant work was making sets of very precise seismographs. Vilip perfected the seismograph by adding an original pendulum and thermocompensation making his seismograph one of the most accurate ones in the world in terms of constancy of the oscillation period and the zero-point stability. In 1925–1939, Vilip's seismographs were produced for 22 largest seismological stations of the world such as those in Copenhagen, Cracow, Stuttgart, New York, Cairo, Beijing and Wellington. The idea of electrical separation of minerals conceived at Tallinn University of Technology was widely employed in the mining industry all over the world.

(9) Outlines of advancing chemical thought

The first book in Estonian containing knowledge on chemistry was the reading book by George Gottfried Marpurg (1805). The author said in the foreword that the book was mostly for farm children and their teachers. Since the principal activity of peasants was cultivation of land, students as future farmers were given instructions of how to fertilize land by suggesting they use lime and marl beside manure. The following textbooks, although still primitive, widened the perspective and clarified the terminology in chemistry. The first thorough overview of chemistry was written by Jaan Kompus, an alumnus of Valga teacher training college, in 1887. Based on German textbooks, the author tried to write a text providing both students and people self-studying a more or less comprehensive picture of the basics of chemistry. Among theoretical issues, the atomic molecular theory was in the centre of attention. The part on organic chemistry took the needs of practical affairs of life into consideration. The manuscript was never published since that was the time when the Russian government prohibited the Estonian language to be used at schools and banned also Estonian textbooks. The first Estonian textbook on basic chemistry was published only in 1908. It was compiled based on English sources. Georg Landesen and Michael Wittlich, in the fields of anorganical and technical chemistry respectively, were elected the first professors at the University of Tartu department of chemistry when Estonian became the language of instruction at the University. Another chair was established for technical chemistry — that of anorganical technology. Yrjö Kauko, a Finn who had done his doctoral degree in Karlsruhe, was endowed the professorship and his activities proved very productive. He taught courses in anorganical and electrochemical technology, technical thermodynamics and physical chemistry, conducted laboratory courses, supervised research work, and introduced seminars and colloquia to his courses. Adolf Gustav Parts, a known physiochemist whose most productive work was research into molecular structure related physical properties, was his student. For a prolonged period of time, he worked at the laboratories of Arnold Eucken in Goettingen, Enrique Moles in Madrid and Hugo Frick

on Long Island. In 1936, Parts was appointed head of laboratory for physical chemistry at Tallinn University of Technology. His work during the Tallinn period focussed on corrosion of metals, amino acids and specific issues of colloid chemistry. He was the first in Estonia to apply the methods of quantum mechanics in research and teaching. World War II took Parts away from his native country and he worked as a lecturer at universities in Ankara and Sidney. Since the 1920s, oil shale and phosphorite have been important objects of research for Estonian scientists. In Tallinn, research was centred at the National Experimental Laboratory and in Tartu an oil shale laboratory was established at the University. The national oil shale industry established its own laboratory in Kohtla. In close co-operation with research institutes in London and Zurich, the basics of the technology for producing oil and petrol from oil shale were worked out. A Pleiad of distinguished chemical engineers and engineers as well as researchers of industrial laboratories has pursued research in those issues. In addition to chemical technological matters also issues such as employment of oil shale as an energetical resource and utilization of residue of oil shale burning were studied.

(10) Connections with scientists from Poland and other countries

Contacts in the field of natural sciences developed. In 1923, Dr Aleksander Audova, member of the editorial board of the magazine "*Loodus*" ("Nature") visited Poland — he spent some time at the University of Lwow as a grant-aided scholar. The Lwow School of functional analysis formed by Stefan Banach and his students Stanislaw Mazur, Wladyslaw Orlicz and Julius Pawel Schander in Poland in the 1930s had strong influence on the formation of the views of Professor Gunnar Kangro (1913–1975), an outstanding Estonian mathematician. He was especially fascinated by the Mazur-Orlicz theory of suminability he later explicated. During the Interwar period, the University of Tartu granted honorary doctorates to nine outstanding Polish academics, including four in natural sciences: mathematician Waclaw Sierpinski and mineralogist Stanislaw Thugutt from the University of Warsaw, Wilhelm Borowicz, specialist on steam turbines from the Technical University in Lwow and Bronislaw Rydzewski, geologist from Vilnius Stefan Batory University. The University of Technology in Danzig (Gdansk) that had been declared a Free City with the Treaty of Versailles played an important role in the education of Estonian engineering intellectuals — Estonians mostly studied construction and architecture there. The study programmes of the University were highly though of in Estonia, especially because of the balance between engineering and art related subjects. The increasing cost of living stemmed the flow of Estonians to Danzig and by the end of the 1920s it stopped completely. Another preferred place of studies was Warsaw. The Polish government yielded considerable advantages to Estonians for studying engineering by offering them free tuition, free of charge accommodation and means of instruction. The Polish — Estonian Academic Circle facilitated overcoming difficulties of adapting to new circumstances; lectureships of the Estonian and Finnish languages were opened at the University of Warsaw. Favourable conditions for studying attracted a great number of Estonians interested in technology and engineering. Almost 30 students from Estonia simultaneously studied at Warsaw University of Technology throughout the 1930s. Poland assisted Estonia in training pilots and educating aeronautical engineers. Estonian aircraft constructors tested their aircraft models at Warsaw Institute of Aviation. In addition to studies, Estonia and Poland mutually organised opportunities for students to do their required practical work in summer. The University of Technology in Brno became another popular place for studying among Estonian students due to liberal organisation of studies. Several internationally recognised professors such as Viktor Kaplan (hydro turbines) and Aurel Stodola (steam and gas turbines) taught there. About 20-strong Estonian student community existed at Berlin-Charlottenburg University of Technology. Not so many Estonian students studied also at universities in Darmstadt, Karlsruhe and Munich etc. Interest in studying in Great Britain and France increased. According to the Ministry of Education, 252 Estonian students studied abroad in the 1938–1939 academic year, including 133 students of technology and engineering.

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