David Dunér, Institute of Cultural Science, Lund University
Christopher Polhem 1661–1751. Technical innovations and the metaphoric thinking

The project aimed to shed light on, with Christopher Polhem as the case study, how technical innovations emerge and how technical entrepreneurs succeed in their projects. The original objective of the project has remained the same throughout the whole working process. In order to answer these questions a method based on cognitive theory has been developed, concerning spatiality, categorisation, and metaphors.

Results
1) The research project shows how metaphors and categories have been used in scientific and technological thinking. Polhem's thoughts on a universal language was guided by a couple of basic metaphors, such as 'categories are boxes' and 'the world is a set of building blocks'. These metaphors capture also two central problems of Baroque thinking, firstly, classification and atomisation of things and concepts; and secondly, the question of the certain method for transferring and receiving knowledge or create new knowledge. Polhem and others based their thinking on the belief that nature had order, and that this order is possible to discover and describe, that things have special essences, that words are or should be isomorphic to the things. The concept of categories Polhem had was of a classical sort. The categories were defined by their objective qualities that were shared by the members of the category. Categorisation depends on knowledge about the essential properties of category.

Through an understanding of his experiences with the help of objects and substances he could categorise and group them, quantify them and think about them. The universal language is a dream of a language with fixed meanings, the search for unchangeable concepts, a longing for lucidity and the closed, absolute system. It was natural for Polhem and others to view the categories as existing outside the human mind. He believed in a universal, transcendental logic beyond the human being. The universal language reflected the true structure of reality. An understanding of Polhem's thinking is about to find such cognitive tools, to find the 'boxes' or categories he used. These are actually dependent on his experiences, beliefs, perceptions, movements in space, and the culture around him, but also on metaphors and mental images.

2) The research project also shows how the spatial thinking actuate technical innovations. Spatial conception develops in interaction with the surrounding world. Firstly, I have found that vision and self experience have a central significance for technological thinking; and secondly, that spatial thinking has an important role in the invention of new technology and in understanding the motions and power transmission of mechanics. In this way, through the experience of his eyes and hands, Polhem learnt new technology. The inventor imagine technology in mental images, both as mental models and as

representations, but also with help of distributed cognition, where thoughts are placed outside the brain as physical models of reality in wood.

Polhem invented machines in his mind. He had a special spatial ability through which he in his mind could put together the mechanical parts into complex machines. It is basically a spatial, non-verbal thinking that can be seen in his technical inventions. Technical solutions and scientific ideas existed first as visions, like images without words in the mind. Thereafter could the inventor try to translate the mental image into words or transfer the inner image to a drawing on a paper or to a model, in order to arouse similar mental images in an other mind, and finally a constructor constructs the mechanical ideas in three dimensions. Polhem's inventions are based on such mental images. The spatial thinking gives clues to how inventors thinks about machines, how they with inner images construct new technology in their minds, through vision, observation and models.

3) A complete inventory have been made, collecting all known sources concerning Polhem. Some until now unknown sources have been discovered, both in Sweden and abroad. For the first time an overall picture of Polhem's all activities can be put together in a monograph.

New research questions
A couple of research questions have shown to be more fruitful than what was first assumed, e.g. categorisation and vision in order to develop new technology. In all, the project has led to the possibility to go on with research questions grounded in cognitive theory, such as situated and distributed cognition.

Publications
The most important publications of the project are: 1) 'The Language of Universe: Polhem and the Art of the Alphabet' (32 pp.), published in Lychnos 2007. This article concerns Polhem's thoughts about a universal language, a perfect, logical language that could be spoken by all human beings independently their culture or nationality. The article goes through many of Polhem's longer or shorter sketches of a such formal language and place them in the context of the semantics and philosophy of the time, and not at least the ability of categorisation that signify human thinking. A continuation of this article, as a freestanding part two, is the article 'The Alphabet of Nature: Polhem and Linnaeus Concerning the Systematics of Plants'' (40 pp.), published in the annual of the Swedish Linnean Society for 2008. In this the rest of Polhem's manuscripts about universal language is analysed. In these Polhem categorise the things of nature and plants, explicit as an alternative to the systematics of Linnaeus. The article is about systematic thinking, order of nature and human categorisation of plants and animals. 2) 'Models of Reality: the Model maker Polhem, Vision and the Spatial Thinking' (20 pp.), published in the annual of Lund Society of Sciences for the year 2009. In this article the spatial thinking is discussed and its significance for innovations and technology, how visual

representations, inner mental images and spatial ability effect technological thinking. And further, it goes through Polhem's models and other spatial and visual representations of technology.