About Methodological Foundation of Interdisciplinary and Transdisciplinary Research

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- ”There is a growing emphasis for encouraging creative thinking in mathematics education and needs to develop connections of mathematics with other subjects. Activities focusing on the creative process, rather than concentrating on achieving only results for posed problems, are being designed and trialled by innovative groups around the world.”

Science Education and Philosophy and History of Science

- “Science teaching occasions philosophical questions which thoughtful teachers and curriculum writers have long engaged. These questions encompass educational ones about the place of science in the curriculum, and how learning science contributes to ideals of an educated citizen and to the promotion of a modern and mature society. The questions also cover the subject matter of science itself. What is the nature of science? What is the status of its knowledge claims? Does it presuppose any particular world view? The first category of questions constitutes standard philosophy of education (PE); the second category constitutes philosophy of science (PS) or history and philosophy of science (HPS).” (Matthews 2006, 342)

Search for Understanding

- At the beginning of my studies in university physics, one laboratory exercise asked me to identify particles on the basis of “their trajectories” in a cloud chamber. To be exact, the cloud chamber was broken at the time, and thus I was given a brief account of the experimental settings and a photography of the resulting situation. It was an easy task to perform with the given step-by-step directions, but I felt very uncomfortable with it. I did not see any connection between the lines of the photograph and the particles indicated by the established theory. At this point I recognized that the philosophical approach can support the understanding of physics. (Tala 2015)

About Logic of Experiment: Experimental Questions

- The experimental setting is a strategic plan in which the inquirer formulates a information gathering process that yields the intended knowledge.
- In an experiment, the inquirer is not a passive observer but an active searcher for new knowledge – strategic search for knowledge.
- Experimental questions:
  - Presupposition is that there is a functional dependency between variables: $(\exists f)(\forall x)S[x,f(x)]$,
  - How does the observed variable y depend on the controlled variable x? That is: bring it about that $(\exists f)\ K_I(\forall x)S[x,f(x)]$

About Logic of Experiment: Unification of Factual and Conceptual Knowledge

- The experiment gives the observational answer: $K_I(\forall x)S[x,g(x)]$.
  - The function g is function-in-extension – factual information.
  - The inquirer “observes” the function g
- The experiment should give the information that allows the inquirer to know the function which characterizes the dependency:

$(\exists f)K_I(\forall x)S[x,f(x)]$

  - The function f expresses mathematical (conceptual) knowledge
- However, there is no direct access from the function-in-extension g to mathematical function f. The inquirer has to know which mathematical function g is (conclusiveness condition) which connects factual and conceptual knowledge:

$(\exists f)K_I(\forall x)(g(x)=f(x))$.

- Experimental Inquiry exemplifies Constructive Epistemology

Inseparability of Conceptual and Factual Knowledge

- The inseparability is built up into the entanglement of the kinds of knowledge in our epistemic practices – in experimental setups which throws new light on the Quine's thesis of the inseparability of factual, linguistic and other conceptual knowledge.
- Model construction: "the modelling guides the experimental process from planning the experimental setup to the interpretation of the results, and at the same time, modelling becomes developed with this objective of guiding in mind and it is validated by its ability to do it" (Tala)
- The logic is similar in logical (qualitative) inquiry as it is in mathematical (experimental) inquiry.

Mathematical and Logical Inquiry

- Conceptual foundation of inquiry
- Mathematico-conceptual inquiry (quantitative):
  - Mathematics shapes and enables work in many different disciplines, from the natural and physical sciences to the social sciences and fine arts and digital humanities (cf. history of experimental sciences)
  - Applicability of mathematics (Calculus)
  - Mathematics can thus be thought of as a root or foundation for many disciplines (experimental sciences) (Strijbos 2017)
- Logico-conceptual inquiry (qualitative):
  - Game theory (economics, social sciences)
  - Graph theory; theory of trees (social sciences, decision theory)
  - Qualitative analysis (social sciences, humanities)

Generic Notions of *multidisciplinarity* (MD), *interdisciplinarity* (ID), and *transdisciplinarity* (TD)

- Thompson Klein (2017) refers to three basic ideas of interdisciplinarity. First, she mentions bridge building which means that two (or more) complete and mature disciplines are connected in solving problems. Second, she mentions restructuring of two)or more) disciplines by taking only part of the existing discipline to achieve a new coherent theoretical whole. Third, she mentions the possibility that a new theory subsumes theories of other disciplines (transdisciplinarity).
- The notion of multidisciplinarity does not suppose deep integration of disciplines, but, as OECD classification says, it is merely “[j]uxtaposition of various disciplines”.

Methodological and Theoretical Integration

- Methodological interdisciplinarity refers to possibility to borrow methods (or notions) from some other discipline in order to test hypothesis or answer research questions. This is closely related to theoretical interdisciplinarity in which analysis of some specific problems the integration of notions and results of different disciplines are integrated. The integration entails unification of models of the disciplines.
- The mathematical and logical inquiry above show how methodological interdisciplinary research can be generated.

Problems

- There are several “challenges related to the ideas of integration and knowledge systems in extra-academic transdisciplinarity (TD). Philosophers of science are only starting to pay attention to the increasingly common practice of introducing extra-academic perspectives or engaging extra-academic parties in academic knowledge production.” (Koskinen & Mäki 2016, 419)
  - Characterizations are overly optimistic with regard to integration,
  - The notion of knowledge systems is problematic
- Wicked problems may reflect rival schemes of values.
  - They are perceived differently by the different groups it touches,
  - Different approaches may involve different understandings of the problem.
  - Integration of values and the integration of knowledge systems might be seen as one and the same process.
  - The conflation of the axiological and the epistemic may result in problematic outcomes.
  - Danger of pseudo-integration
- Snow’s two cultures