The emergence of Microdata Analysis and its intellectual history over the past two decades

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Editor: Hasan Fleyeh

Nr: 2021:01
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This version: 2021-01-30

Abstract

By 2020, students of Dalarna University had produced some 100 Bachelor and Master’s theses and 25 Licentiate or Doctoral theses in the academic discipline of Microdata Analysis guided by the university’s faculty. While firmly rooted in the tradition and the format of the formal sciences Computer Science and Mathematics, the theses are disparate with regard to area of investigation, research method, and epistemology. The research carried out in these theses is recognized internationally by learned societies and their journals and conferences, yet Dalarna University remains globally unique in labelling an academic discipline Microdata Analysis. This paper attempts to narrate the history of the forming process of Microdata Analysis at the university and grasp its nature.

1. Why, and some instructions and caveats

In February 2020 it had been scheduled an internal workshop for the supervisor group and PhD-students in Microdata Analysis. Two main issues were on the agenda – identity and future vision. I had been asked to reflect in advance on the subject’s evolution. For external reasons the workshop was cancelled, and then the Corona pandemic broke out. Thus, the seminar never happened. Nonetheless, I was instructed to put some of my tacit knowledge on paper and that is what you are reading. The instruction makes sense: an attentive young colleague who read an earlier version made, to my surprise, the remark that I am the only one who has lasted in office of the eleven professors (listed in the beginning of Section 4) that formed Microdata Analysis in 2008.

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The scope of this paper is to recount important passages and development in forming the academic discipline of Microdata Analysis. The aim is to provide a basis for intellectual exchange in the interest of future development of the discipline. In writing the paper I have circulated earlier versions to some 20 heterogenous colleagues and from their feedback I like to give some instructions and make some caveats. First and foremost, stop reading here and turn to Wickson et al. (2006) if the notion of transdisciplinarity is unfamiliar to you! Second, do not expect a scientific paper nor a report. It is neither. It is a mere (mostly chronological) recount of important events for Microdata Analysis. Third, do not expect to be able to deduce the intended target group. I have no message in particular to send, I simply wish that seniors and juniors, insiders and outsiders debate future Microdata Analytical enterprises on an equal historical footing.

2. Microdata Analysis – the subject under examination

As a courtesy to the reader it is customary to initially offer a definition of the subject about which one is writing. I will not do so here as it would be in conflict with the intellectual nature of Microdata Analysis (MDA). Actually, MDA was first defined by the researchers involved at Dalarna University already in 2009 as part of an application to the Swedish Board of Higher Education and the definition will be stated below, however its usefulness is limited to administrative purposes. Schommer-Aikins, Duell, and Barker (2003) suggest at least three ways in which disciplines differ: area of investigation, research methods, and epistemology. This static characterization of a discipline’s research, in today’s research society, is challenged by Gibbons et al. (1994) who coined Mode 2 to refer to research characterized by multidisciplinary teams brought together for short periods of time to work on specific problems in the real world for knowledge production. As they put it: "We now speak of context-driven research, meaning research carried out in a context of application, arising from the very work of problem-solving and not governed by the paradigms of traditional disciplines of knowledge.” The Mode 2 research calls for what is referred to as transdisciplinarity – a notion elaborated on early by Wickson et al. (2006), who distinguish transdisciplinary research by: (i) problem focus, where reality is taken to exist, (ii) evolving methodology, where it is presumed that dissolution of disciplinary boundaries is necessary for the construction of novel or unique methodologies tailored to the problem and its context, and (iii) collaboration, where knowledge is expected to be generated collaboratively between researchers and stakeholders to the problem, be that industrial, organizational or societal.
The external pressure on research institutes and universities to accommodate a Mode 2 research logic has been strong over the last decades. Helga Nowotny has chaired the European Science Foundation, the European Research Advisory Board of the European Commission, as well as the European Research Council. She was also a co-author in Gibbons et al. (1994), where Mode 2 research was brought to light. Unsurprisingly, the European Commission’s current framework program for funding research, technological development, and innovation, known as Horizon 2020, regards society as a stakeholder for research and calls upon universities to collaboratively solve societal challenges. Cohen and Lloyd (2014) take an evolutionary view on the development of academic disciplines and purport that a transfer to transdisciplinarity provides a strategy for the more likely survival of a research community. Indeed, the Mode 2 logic of Horizon 2020 has spread to national and regional research funders in EU’s member states, implying that the large bulk of research funding for university staff is offered by funders assuming a Mode 2 logic, as predicted by Gibbons (2000).

As an illustration of the Swedish research funding opportunities offered to a researcher, Figure 1 presents funding bodies in the Swedish research and innovation system. The rectangles represent the size of the funding source. Essentially, only two bodies “Vetenskapsrådet” and the Swedish government’s direct channeling of research funding to universities (Universitet & Högskolor) sponsor within-academic discipline research, at the discretion of the discipline’s internal research questions. As can be deduced from Figure 1, this funding logic amounts to about 5% of total research funding opportunities for a researcher. All other bodies, as problem-owners or representatives of such, operate under a Mode 2 logic issuing calls specifying the problem or challenge to be addressed in the research project.

In relating the intellectual history of MDA, it is important to recognize the above-described societal trend in science and higher education. The first installation of (two) full professors at Dalarna University (DU) happened simultaneously with the publication of Gibbons et al. (1994), indicating that research at DU dates back to the introduction of Mode 2. It could be expected that a research culture would emerge which comprised researchers subscribing to the Mode 2 logic and attracting research fellows from elsewhere. Given that DU had no pre-1995 research, the strength of traditional academic disciplines would be weak, leaving the field open for a swift accommodation of a Mode 2 logic at DU.1 To underscore this point it is helpful to

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1 Jansen (2002) presents a description of a South African university’s struggle to transfer to a Mode 2 logic.
observe that none of today’s five full professors in MDA at DU have maintained a within-disciplinary focus in their research and teaching upon completing their doctoral degree. On the contrary, these professors are problem-focused in their research introducing and relying on methodologies also outside their discipline of origin, continuously revitalizing their set of collaborators.

Figure 1: Research and innovation funding bodies in Sweden, with the size of the rectangles indicating the monetary size of funding for a body.  

Suggesting that MDA is transdisciplinary in nature, one can naturally pose the question of whether it evolves organically, being at every instance in time amorphous? There is no simple answer to this question. It would be correct to deduce that the composition of the faculty’s knowledge and skill-base, its internal collaborative skills, and issued calls dynamically define

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2 Kungl. Ingenjörsvetenskapsakademien (IVA), 2011, “INNOVATIONSPLAN SVERIGE – underlag till en svensk innovationsstrategi”.
the project members and areas of investigation, research methods, and epistemology. However, the supervisor group provides a conservative function in having scale-economic incentives to enforce an insistence on these three dimensions, as well as being held accountable for the quality of the research conducted under the auspices of MDA. The relevance and success of MDA, as for any other transdisciplinary environment, is largely dependent on its ability to reflect on the appropriate balance between dynamics and adapting to calls, and the counteracting conservatism.

3. Previous to 2008 and before the introduction of the notion of MDA
The faculty in MDA over the years are connected to the early DU initiative of the CTS (Center for Research in Transports and Social Sciences). The Center was formed in 1991 as a joint venture between DU and the Swedish Transport Administration, and the Center’s researchers were exclusively recruited externally for research positions, having no or very limited teaching responsibilities (Borgert, 2013, p. 168). The initiative had a weak alignment with DU’s education at the time, which was dominated by undergraduate programs in Engineering and professional programs in Education. Instead, the Center developed in response to external requests from the local community who wanted to ensure capacity building in Transportation research and education to meet the needs of knowledge-production and labor for the governmental agencies in Borlänge and their local subcontractors in the region. By the late 1990s the center had undergone some organizational transformation and existed both as an organizational unit at DU with research and undergraduate programs, as well as two R&D Centers (VTI – Transport Economics), and TFK (a Transport Policy Agency). Full professors in Transport Economy, Traffic Psychology, Computer Science, Information Science, and Road Technology were recruited and some 10 PhDs were conducting their studies at the site, albeit foremost enrolled in PhD programs at either KTH (Stockholm) or Uppsala University, united by a common interest in transport problems. The intellectual exchange engaging academics from all these disciplines was organized in a weekly seminar series, known as the “VTI Seminar”, open to the local public and private stakeholders in transportation.

Around the millennium, a large research project known as ISA, formerly associated with the Borlänge Science Park, became a gravitating force. The project had some 300 volunteer drivers engaged in testing various prototypes and solutions for driving safety and incentive schemes, where the project foremost relied on research methods prevalent in behavioral sciences.
ISA project received wide and international recognition, partly propelled by an international curiosity for “zero vision”, which set a national goal for zero deadly outcomes in the traffic system. For instance, Kay Axhausen, one of the world’s most cited researchers in transport planning, was at some point engaged in work with and evaluating tests within ISA. Furthermore, when the economist George Akerlof received the Nobel Prize in Economic Sciences in 2001, he opted for giving his public Nobel Lecture on the topic of market failures at Campus Borlänge.

In the early 2000s several one-year master’s programs were launched by the faculty attached to transportation research. These programs were as follows: (with the main field of studies in parenthesis); Artificial Intelligence (Computer Engineering), Applied Microeconomics (Economics), Applied Statistics (Statistics), Intelligent Transport System and Services (Informatics), Operations Research (Computer Engineering), and Transport Psychology (Psychology). In all these traditional academic disciplines appearing as a main field of studies, approx. 20 PhD students were active and engaged in educational programs at the campus during the mid-2000s. Most doctoral projects concerned either life-cost analysis, or data collection and analysis on road and rail infrastructure maintenance, while others focused on business models for innovative products and service, foremost related to the regional IT-industry.

Although the seminar’s topics were dominated by problems arising in relation to transportation, the seminar also hosted issues raising broader normative questions. A sample of questions addressed in the seminar at the time might include: Is it feasible to decide upon railway maintenance plans for inspectors’ data reports?; Will congestion charges alleviate inefficiency in Stockholm’s road network?; Should Sweden join the European Monetary Union?; Would enforcing RFID-tagging of the national wagon fleet be justified with regard to loss of vehicles? How should the Central Bank manage the credit system for systemic risks?

The transdisciplinary nature of the transport environment was constrained by DU’s overarching vision in the mid-2000s, which focused on building strong, traditional academic disciplines in the pursuit of fully-fledged university rights. The economic incentives stimulated within-

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3 “Ansökan om examenstillstånd på forskarnivå inom området mikrodataanalys”, 2011 (Table V in Appendix 1).
4 In a personal communication with Dick Åhman, some macro trends were highlighted that affected DU’s higher management’s view on the issue. At the time, it was argued that universities like DU should serve as colleges, and supply, in this case, Uppsala University with graduates. At DU, there was a concern that research centers not
discipline research and recruitment, coupled with educational programs targeting within-discipline criteria, rather than the knowledge and skills demanded by externals. At the time, several of the senior researchers in the first wave of transdisciplinary research in transportation abandoned DU, whereby research funding attracting skills drastically deteriorated.

The within-discipline stimulus came to an abrupt end when the higher management at DU was replaced by a new president and the vision had proven unsuccessful. In 2008, DU launched its first research strategy to come into action for the period 2009-2011. Thereby, the logic of disciplinary research was abandoned in the interest of, if not transdisciplinary research, at least interdisciplinary research, by combining the disciplines into clusters, referred to as research profiles, with an appointed decision-maker for each profile’s research. Most of the researchers from the transportation research environment transferred to a research profile named Microdata Analysis and E-infrastructure. Incidentally, the name Microdata Analysis appears for the first time at DU in this research strategy document.

![Unstructured data](image)

Figure 2: The observed and projected growth in structured and unstructured data at the time of the first introduction of the notion of Microdata Analysis.

The data-analytical methods employed and the technical skills of the researchers in the first transdisciplinary wave presumed structured data (cf Figure 2). In DU’s analysis leading up to the research strategy and the forming of the research profile in MDA (for short), several observations had been made. The first was that Sweden offered generous access to public

connected to educational programs would risk DU’s development by offering degrees at a higher level than a bachelor’s degree.
(administrative) data, which had proven a competitive advantage for Swedish researchers in forming international research teams and addressing research questions with wide international interest. A second observation was the digitalization of public service as well as an anticipated growth in e-services on the market, which would call for a substantial need for standardization. Thirdly, data management methods, data analytical methods and decision support systems that managed both structured and unstructured data taken together were of a drastically larger magnitude than ever encountered before.

4. MDA in the research profile Microdata Analysis and E-infrastructure 2008-2011

In May 2008, the MDA research profile came into force. Formally, all the faculties as well as PhD students at DU in the academic disciplines of Computer Engineering, Electro Engineering, Informatics, Information Science, Geographical Information Systems, Production Technology, Road Technology, and Statistics were combined in the research profile. In the Work Plan\textsuperscript{5} for 2009, some actions were outlined with the aim of re-establishing transdisciplinarity, although, perhaps, more realistically, on a short term, an interdisciplinary culture in line with the governing research strategy of DU in force 2009-2011. A collegial call had preceded the formation of the research profile, and 11 associate and full professors were enlisted; Magnus Bohlin (Human Geography, GIS), Johan Bring (Statistics), Kenneth Carling (Statistics), Mark Dougherty (Computer Engineering), Owen Eriksson (Informatics), Changli He (Statistics), Gunnar Isacsson (Transport-Economics), Jerry Johansson (Industrial Engineering), Rickard Lindgren (Informatics), Rolf Magnusson (Road Technology), and Fan Yang-Wallentin (Statistics), of which almost all had a vested interest in transportation research.

The complementary knowledge and skills of this faculty were promising, but the lack of earlier collaboration and common scientific language was imperative to overcome. Proposed aims were therefore to (i) form a joint supervisory group consisting of associate and full professors in the research profile, (ii) initiate a joint seminar to serve as an intellectual arena for researchers in the profile, (iii) initiate joint research projects spanning over the competencies and make use of the complementary skills, (iv) reform existing Master’s programs to achieve synergy across the traditional academic disciplines naturally falling into the research profile, and (v) achieve

\textsuperscript{5} “Verksamhetsplan och ansökan om interna medel för 2009”, Research profile Microdata Analyse & E-infrastructure, 2008-08-14.
an integration of PhD students in the research profile, who at the time were scattered and connected to several departments and universities, such as Chalmers, KTH, Linköping, Örebro, as well as universities abroad.

The supervisory group has met ever since, 2-3 times per semester to set the work agenda with regard to primarily managing PhD students, reviewing research proposals and planning for future proposals, discussing staffing and recruitment, and reviewing the educational programs (with a primary focus on Master’s and PhD). In MDA’s first Work Plan, the following goals were tactically agreed upon: (a) recruit 2 post-docs with a good fit to the research profile, rather than any specific academic discipline, (b) bring together the (approx.) 15 PhD students site wise and promote their collaboration and intellectual sharing, (c) offer a full semester of PhD courses, focusing foremost on spatial data analysis, (d) develop a joint 2-year master’s program to replace existing 1-year master’s programs, (e) execute a project referred to as Visualized Logistics Simulations, (f) arrange a workshop for PhD-students, and (g) appoint a Database Administrator responsible for the management of databases, including those accessed via regional partnership.

In addition to addressing these tactical goals, the first full professor was recruited as a fit to the MDA profile. This professor was William Song, who had a doctoral degree in Computer and System Science from Stockholm University, although prior to taking on the full professorship in Business Intelligence at DU he had served at Durham University.

The task of developing a 2-year master’s program was assigned to Magnus Bohlin, who, at the time, chaired one of the collegial boards at DU, and his task force consisted of a group of five PhD students.6 The task force proposed a master’s program in Business Intelligence, and the application was submitted to the Swedish Board of Higher Education in October 2009. The application provides the first definition of the subject of MDA and reports on the profile’s key partners in research.7 While there has been slight modification to the administrative definition of MDA over time, the definition read and still reads essentially as:

6 The Bologna process was concluding and it had established the definition of curricula focusing on the work-life relevant learning outcomes of students, rather than within academic discipline education.
"The subject of Microdata Analysis concerns complex processes in business and industry, and the built environment. Microdata Analysis is a multidisciplinary field of knowledge that concerns the collection, modelling, compilation and interpretation of large data sets, together with underlying algorithms, methods and techniques. Microdata Analysis includes several interrelated domains such as artificial intelligence, decision support systems, management of limited resources, data modelling, design of experiments, focus groups, geographic information systems, visualization, measurement techniques, optimization, forecasting, simulation and statistical inference. This is a normative subject aimed at data-based decisions and actions."

It should be noted that in 2010 the Swedish Board of Higher Education approved the Microdata Analysis program, where the outlined Business Intelligence Master’s Program fulfilled the role of exemplifying a program that could permissibly run under this definition. Nonetheless, the outlined program was also that which came into force with the approval.

To prepare for the program, during 2009 the MDA Seminar focused heavily on research problems and solution methods in Business Intelligence, and the International Journal of Business Intelligence Research, at the time hosted by Saint Joseph’s University as the forerunner in Business Intelligence education, was a recommended outlet for the faculty’s research. Simultaneously, the faculty were active in organizing and participating in the annual conferences of the Web Information Systems Engineering Society.⁸

The application, as of 2009, gives a good overview of the research and education activities in MDA at the time, so only a few examples will be mentioned here to illustrate what research was in focus at the time. The first is the project mentioned as the tactical goal (e). The problem-owner was the Salix Maskiner AB company, located in Hedemora. They produced add-ons to trucks and tractors, so the vehicles could serve multi-purposely in an agricultural process from sowing and harvesting to transporting to mills. The problem the management faced in selling the add-ons was a difficulty in communicating the business value to potential buyers. This problem was presented in the MDA Seminar, during which emerged a solution of gamification whereby a software would allow the Salix representatives to set up the current logistic operations of a buyer to be contrasted with the counterfactual logistic operations, were they to equip their machinery with the marketed add-ons. The software visualized the daily, logistic

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⁸ http://wise-conferences.org/
operations for the fleet on a dynamic map and computed time, money, and fuel saved for the buying company, contingent to their exploiting the add-ons. To build the software, staff from Salix worked alongside the researchers from MDA at the University, with the former sharing their context and business insights, and the latter sharing the programming, visualization and operations management know-how. Incidentally, the project had as a spin-off the initiation of KTP (Knowledge Transfer Partnership) which later came to be an important model for how DU collaborates with industry. Since Salix was a rather small company it did not aspire to engage deeply in R&D.

The visualization project had however an offspring a few months later with the company Bergkvist Sawmill outside Leksand, where the problem-owner at the sawmill was facing the following problem. The sawmill relied on incoming timber arriving by trucks, and the trucks operated under the loosely-formed organization “Skogsâkarna” in a highly uncoordinated manner. The sawmill, however, required a predictable flow of logs in order to make best use of the internal (i.e. within the sawmill) logistics. Businesswise, the forest value in the region was largely determined by the price of timber in Bavaria (Germany), discounted by the transportation costs of moving the timber from the forests in the region via the local sawmills to the Bavarian market. It was believed that the lack of coordination of timber transport and the consequent lack of predictability in the sawmill operations gave rise to substantial inefficiency with dire economic consequences. The problem was discussed both at the sawmill with the owners, as well as in the MDA Seminar. The idea of attaining greater coordination amongst truck drivers was dismissed in light of the insights of the incentives’ structure for the timber carriers. The principal solution purported that the driver should text a photo from the back of the loaded timber truck to a server. Image analysis and machine learning were used to assess the quality and the volume of the load, and a routing model exploiting the time and the position of the truck predicted the likelihood of the truck aiming for the sawmill and the arrival time. The Salix software was reshaped as a decision tool within the sawmill steering the internal drivers at the sawmill between truck off-load, scanning station, sawmill feeding station, warehouse and railway station. This project spanned over almost all methods presented in the definition of MDA, and made use of the collective expertise of the faculty members as well as several PhD students. Regrettably, the project was never completed as it ran out of funding. An application to the Knowledge Foundation (KK) was prepared, but DU did not fulfill the requirements regarding supporting documentation. Instead, the know-how attained in the above-mentioned projects was transferred to a focus on decision support systems in health
monitoring, as well as infrastructure maintenance where alternative research funding could be secured without being affected by DU’s higher managements’ disapproval of industrial R&D.

The resulting visualization project in health monitoring was technically manageable, owing to the graduation of several PhD students, under the supervision of Mark Dougherty, at the time specializing in analyzing unstructured data by machine learning in transportation. The students involved in this project were as follows (with year of graduation in parenthesis): Siril Yella (2006), Hasan Fleyeh (2008), Roger Nyberg (2016), and Jerker Westin (2010), all having been critically important for building MDA’s capacity in analyzing and modelling unstructured data.

The latter student of the four had, however, health analytics as his area of investigation, and formed a cluster within the MDA environment working with complex processes in the medical informatics (MI) domain. According to the Swedish Association of MI, this domain is the transdisciplinary science concerning the management of data, information and knowledge in the medical sciences and healthcare. There is a clear intersection between MDA, as described above, and MI. The focus of the MI cluster has been on researching data- (and knowledge) driven decision support directed towards healthcare personnel and patients’ self-care by optimizing personalized treatments. Several research projects have been completed aiming at measuring symptoms and optimizing levodopa delivery in Parkinson’s disease. This problem domain has required deep knowledge in clinical neurology and neuropharmacology and the research has been performed in close collaboration with the Swedish University hospitals, in particular with those at Uppsala, Karolinska and Sahlgrenska. Methods developed and applied include video and sound processing, signal processing, including wavelet transforms and entropy, machine learning, such as support vector machine regression, mathematical modelling and simulation of drug transport and effect, optimization methods, man-machine interfaces and gamification and clinimetric test evaluation methods. All research carried out in the MI cluster has been conducted in co-production with business partners, including Clinitrac (patient diary apps), Neopharma, Solvay, Abbott, and AbbVie (intestinal levodopa pump treatments), Nordforce (mobile communication), Cenvigo (medical measurement technology), Global Kinetics (wearable sensors) and Sensidose (micro-tablet dispensing devices). The research has attracted over 15 MSEK in external funding to DU, mostly from Knowledge Foundation (KKS) grants (KKS-IDOL 2003-2006, Grant from Solvay 2006-2007, KKS-MOVISTAR 2007-2010, KKS-E-MOTIONS 2010-2013, KKS-PAULINA 2013-2015, VINNOVA-MUSYQ 2015-2017, KKS-FLOAT 2015-2018, KKS-EMPARK 2017-2020) and more than double this
amount, counting project contributions by the business partners. Outputs of the projects have been 5 PhDs (Jerker Westin, 2010; Mevludin Memedi, 2014; Taha Khan, 2014; Ilias Thomas, 2019; Somayeh Aghanavesi, 2020; and one docent (Jerker Westin, 2015), as well as 3 patent families, more than 30 journal articles, and 40 conference presentations, and product and business development in the companies.

Another influential capacity-building project was “Test and Demonstration Arena – E16” (TDAE16). This emerged after the association ITSdalarna carried out seven pre-studies commissioned by Vinnova. ITSdalarna engages some 40 companies and public entities with an interest in Intelligent Transport Systems and services. The bottom-line of the pre-studies was that local growth could be achieved by setting up a test and demonstration arena where ITS-products could be tested in a prototype phase, and data could be exchanged across organizations for the development of new smart products. The pre-studies led to a large Vinnova-funded project aiming at building a data exchange and developing business models for products emerging from this opportunity, as well as a physical testing arena along the E16 route, with a concentration of test sites around Borlänge. MDA had primary responsibility for the data exchange, but it was also engaged in the physical testing site.

The fundamental know-how acquired by the MDA-faculty from the TDAE16 project was how to develop products and derive business models for immaterial products and services, and as an example of more general knowledge production a PhD thesis was produced that demonstrated how an intelligent vehicle sign might reduce the speed variation on local streets, thereby lowering the risk of traffic accidents. It was the first project in transportation where business value and business modelling were an important aim of the project, thus stimulating MDA to connect with business expertise. Horizon 2020 borrows the TRL-scale from NASA, which in the former’s application expresses how a research project falls between pure research (level 1) and market uptake (level 9). Horizon 2020 distinguishes in their calls between Research and Innovation Actions (RIA, levels 1-3), Innovation Actions (IA, levels 4-6), and Coordination and Support Actions (CSA, levels 7-9). Prior to the TDAE16 project, MDA could only aspire to RIA and IA calls, while engaging the business expertise opened up for responding to CSA calls as well. This may seem a simple matter of organizing a research team for a specific call, but in general an interdisciplinary team is inadequate for achieving the goal of a CSA call – transdisciplinarity is required, and TDAE16 was the first instance where transdisciplinarity was attained by MDA.
The research and intellectual exchange carried out at MDA broadly engaged the faculty and the PhDs, stimulated by problem-owners presenting their problems at the MDA Seminar, and solutions were collectively discussed in the seminar or in relation to it. The supervisory group took the responsibility of seeking funding for problems that were particularly appealing to the MDA faculty, based on collegial discussions. The faculty and PhDs were however also connected to their original academic disciplines, as it was not considered important to formalize MDA into a conventional academic discipline. Quality assurance of research was done by publishing produced research in traditional journals, depending on the area of investigation, research method, and epistemology of the research. However, this implied an unfortunate restriction on the research and when the profile was submitted to external review in 2010 the reviewer pointed out the need for finding more appropriate journal and conference publishing outlets for the transdisciplinary research conducted in MDA. At the time, the dominating area of investigation was transportation, which, however, is a research area with high tolerance for transdisciplinary approaches.

5. MDA in the research profile Complex Systems – Microdata Analysis 2011-2016

In the summer of 2010, DU signed an agreement with Örebro University regarding enrollment and supervision of PhD students. This agreement opened up the opportunity for the faculty in MDA to serve as principal supervisors for students enrolled at Örebro, but who were employed and active at DU. This agreement substantially improved the structural integration of PhDs in the research conducted within the research profile. In the fall of 2010, half of the PhDs in the research profile were enrolled at Örebro. However, they were enrolled in different academic disciplines which hampered the research as the PhDs had to comply with within-discipline norms that were weakly justified by the research goals, as well as making seamless collaboration between students tricky. To overcome this problem, the supervisory group strongly requested the establishment of PhD program under the auspices of MDA, properly reflecting, and training for, the research challenges and opportunities that the supervisory group envisioned for the future.

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10 See ”Forskning vid Högskolan Dalarna – en presentation av forskningsstrategin 2009-2011 och 161 pågående forskningsprojekt”.

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The faculty and some PhD students had put substantial intellectual activity into developing the application for the Master’s degree in MDA, where the local learning outcomes and prerequisites in the educational plan were discussed most extensively. The local learning outcomes required a consensus amongst the faculty on what constituted minimum requirements for a student with regard to knowledge and skills in the MDA domain, as those outcomes were a detailed specification of the general learning outcomes for a Master’s degree. One reason for the extensive discussion was that the faculty, originating from disparate academic disciplines, had to learn, assess, and adapt to the scientific language and norms of fellow faculty members. Further, to set the prerequisites the faculty needed to agree on realistic learning trajectories for students under a two-year training program. Hence, pedagogical traditions and their results were also deeply reviewed by the faculty to enable the setting of prerequisites.

The MDA academic discipline was deliberately low-key in its formation years to establish an interdisciplinary environment with a collective understanding of scientific language and research approaches amongst the faculty. However, in 2010, another influential research project came to light providing an opportunity for further progress towards transdisciplinarity. This came in response to a joint call from the Swedish Retail and Wholesale Council and FORMAS (the Research Council for Sustainable Development), where DU and HUI Research purported to address the following questions: How well are retail outlets located from an environmental perspective and how can this be measured?, How is the environment affected by consumers’ shopping trips and how can this be measured?, and, How will retailers’ long-term localization and investments be affected by the Stern Report and new environmental regulations and policies? Catalyst for the project was the establishment of an IKEA Outlet in Borlänge with accompanying business that took place at the time. The establishment had given rise to much speculation on how local traffic patterns would be affected. Skills and resources accumulated in the TDAE16 Project became part of this new project that eventually generated approx. 15 research articles published in Business, Economics, and Operations Research journals. Critical to the success of the project, in addition to engaging faculty and PhD students in MDA, was the contribution made by researchers in a former research profile who offered competence in retailing and public economics. The aftermath of this project in the business area is still evident where MDA methods have been adopted, for example, by three PhDs/Post-docs, Charlie Lindgren, who studies how price transparency affects market efficiency, Madeleine Lagin, who studies logistic business models for local produce, and Asif Huq, who studies the phenomenon of social responsibility within firms.
In response to Bo Sundgren’s review and recommendation of finding a suitable, international arena for intellectual exchange in MDA, the supervisory group decided to promote participation in the EURO/INFORMS\textsuperscript{11} held in Rome 2013, organized by the Italian Operations Research Society. A large group of researchers from DU participated and presented some 10 papers emerging from the TDAE16 project. The conclusion was that the forum provided a very good fit for the research conducted in MDA, and the faculty and PhD students have thereafter disseminated their research at conferences organized by INFORMS\textsuperscript{12} and its global associates. In fact, PhD students during their studies are expected to attend and disseminate their research at an INFORMS-sponsored conference.

Returning to the desire to offer a PhD program in MDA, in the winter of 2011, DU’s higher management suggested merging the research profile offering competence in retailing and economics with MDA and submit an application for a doctoral degree in MDA, naming the new research profile Complex Systems – Microdata Analysis. The application for a doctoral degree was to build on and extend the application to issuing a master’s degree in MDA. During 2011, the supervisory group was again confronted with the intellectual challenge of agreeing and defining local learning outcomes and prerequisites for a PhD program, as well as defining the curriculum of the mandatory courses to ensure a common knowledge and skill base for a doctorate in MDA. The reviewers, Christer Carlsson, Professor of Management Science at Åbo University, and Georg Lindgren, Professor of Applied Mathematics at Lund University, concluded that the synergetic elements in the research profile justified the notion of MDA and that it promised to offer exciting scientific opportunities.\textsuperscript{13}

With external support from highly-accredited peers for a complete educational program at bachelor’s, master’s, and doctoral level, as well as several inputs indicating the relevance of MDA as a research environment, MDA had acquired a substantial academic role. Table 1 lists the milestones in this process and how they have affected the research environment.

\textsuperscript{11} https://www.informs.org/Meetings-Conferences/INFORMS-Conference-Calendar/EURO-INFORMS-Joint-International-Meeting
\textsuperscript{12} https://www.informs.org/
In 2013, the first doctoral defense was held in MDA. This was when Mengjie Han defended a thesis that developed feasible solutions to large localization problems, extending on approximation methods foremost developed in operations research. The principle for adequate quality assurance was formulated where three experts in neighboring domains served on the examining committee. Kaj Holmberg (Professor of Optimization, Linköping), Mark Dougherty (Professor of Computer Science, DU), and Andreas Karlström (Associate Professor of Transportation, KTH) served on the committee, each questioning the doctoral candidate from their domain perspective. An important intellectual lesson from this event was the need for the transdisciplinary research to be well-informed about important issues in related disciplines. This insight has further been verified at later doctoral defenses and other research dissemination activities, which has provoked modification in the general study plan of the PhD program so as to ensure PhD students have sufficient skills in absorbing broad research streams.

Table 1. Milestones for Microdata Analysis at Dalarna University

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Affecting</th>
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</thead>
<tbody>
<tr>
<td>1995</td>
<td>Lars Hultcrantz appointed full Professor of Transport Economics</td>
<td>Intellectually</td>
</tr>
<tr>
<td>1997</td>
<td>School of Transport</td>
<td>Establishing a transdisciplinary research culture</td>
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<tr>
<td>2000</td>
<td>Opening of several one-year master’s programs</td>
<td>Bridging research and education</td>
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<tr>
<td>2004</td>
<td>Vision of a Dala University</td>
<td>Inhibiting transdisciplinarity with emphasis on within academic discipline research and education</td>
</tr>
<tr>
<td>2007</td>
<td>Application for a 2-year Master’s degree – Information Science</td>
<td>Intellectually by promoting a cross-disciplinary exchange of research and education</td>
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<tr>
<td>2007</td>
<td>Identification and prediction on the growth of unstructured data</td>
<td>Intellectually and organizational goals</td>
</tr>
<tr>
<td>2008</td>
<td>Setting up of the research profile Microdata Analysis &amp; E-infrastructure</td>
<td>Operational ability, intellectually by facilitating transdisciplinarity</td>
</tr>
<tr>
<td>2008</td>
<td>Start of MDA seminar</td>
<td>Intellectually</td>
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<tr>
<td>~2008</td>
<td>Several PhD’s focusing on analysis of unstructured data</td>
<td>Capacity building analysis of unstructured data</td>
</tr>
<tr>
<td>2009</td>
<td>Forming of supervisor group</td>
<td>Intellectually, quality assurance of research</td>
</tr>
<tr>
<td>2009</td>
<td>Application for a 2-year Master’s degree – Business Intelligence</td>
<td>Intellectually by external feedback, capacity building in collaboration, administrative definition of MDA</td>
</tr>
<tr>
<td>2009</td>
<td>MDA-collaborative projects</td>
<td>Capacity building</td>
</tr>
<tr>
<td>2010</td>
<td>Agreement with Örebro University regarding PhD enrollment</td>
<td>Capacity building of PhD supervision</td>
</tr>
<tr>
<td>2010</td>
<td>External review and feedback from Bo Sundgren</td>
<td>Supervisor group’s insight on the need for adequate research outlets and peers for quality assurance. Insight on the need for not only research output, but also the need of a collective quality enhancing mindset.</td>
</tr>
<tr>
<td>Year</td>
<td>Event Description</td>
<td>Notes</td>
</tr>
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<tr>
<td>2010</td>
<td>Retailing and environment project</td>
<td>Capacity building in retailing as an area of investigation</td>
</tr>
<tr>
<td>2011</td>
<td>Application for PhD program in MDA</td>
<td>Transdisciplinarity in both research and pedagogically</td>
</tr>
<tr>
<td>2012</td>
<td>Initiating PhD program</td>
<td>Organizational with regard to accountability of the supervisor group concerning academic quality</td>
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<tr>
<td>2012</td>
<td>Emergence of Health Analytics</td>
<td>Widening area of investigation</td>
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<tr>
<td>2012</td>
<td>Establishing a Working Paper series in MDA</td>
<td>Intellectually and collaboratively</td>
</tr>
<tr>
<td>2013</td>
<td>Faculty’s and PhD’s attendance at EURO/INFORMS</td>
<td>Intellectually, identification of adequate research outlets and peers for quality assurance</td>
</tr>
<tr>
<td>2013</td>
<td>Losing the race to acquire a center of excellence funded by HUR in retailing to Lund’s University</td>
<td>Economic constraints on the research in Complex Systems – Microdata Analysis</td>
</tr>
<tr>
<td>2013</td>
<td>First Doctoral defense</td>
<td>Principles for quality assurance and peer reviewing and external feedback on the quality of the PhD program</td>
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<tr>
<td>2015</td>
<td>DURE report</td>
<td>External feedback highlighting the need for the research profile Complex Systems – Microdata Analysis to connect with the research community in Analytics</td>
</tr>
<tr>
<td>2015</td>
<td>Submission of the first project “Intelligent Infrastructure of bioenergy in rural transports” to Horizon 2020 as project coordinator</td>
<td>Capacity building on research funding to large Mode 2 calls</td>
</tr>
<tr>
<td>2016</td>
<td>Dean initiates promotion to full professors in MDA</td>
<td>Accountable for MDA are appointed</td>
</tr>
<tr>
<td>2016</td>
<td>SAILOR project funded from ERA-NET and Kamprad Foundation</td>
<td>Capacity building in logistics and business modelling and broadened business network relations</td>
</tr>
<tr>
<td>2017</td>
<td>Assessment criteria for academic positions in MDA</td>
<td>Definition of competency for MDA</td>
</tr>
<tr>
<td>2017</td>
<td>Emergence of Analytics in the Energy Research profile</td>
<td>Widening area of investigation</td>
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<tr>
<td>2018</td>
<td>Holistic reformation of PhD program, Master’s programs, and undergraduate programs</td>
<td>Vertical integration of research and education</td>
</tr>
<tr>
<td>2019</td>
<td>DU recognizes the Doctoral Program Committee of MDA</td>
<td>Quality assurance of the PhD program</td>
</tr>
<tr>
<td>2019</td>
<td>Research program for MDA put forward by the six full professors</td>
<td>Quality assurance of research</td>
</tr>
<tr>
<td>2020</td>
<td>External evaluation of the PhD-program</td>
<td>Quality assurance of research</td>
</tr>
</tbody>
</table>

The research profile Complex Systems – Microdata Analysis, similar to other research profiles at DU, was submitted to a fully-fledged external review in about 2015. The review was conducted by Stina Algotsson (CEO of the R&D fund of the Swedish Tourist & Hospitality Industry), Christer Carlsson (known from earlier reviews), and Lars Hultcrantz (at the time with Örebro University). The panel reviewed the research profile including all educational programs, strongly or weakly connected to the research profile. The panel recommended that MDA should

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collaborate with the Analytics community, which equates to INFORMS. It also expressed concerns about the “lack of enthusiasm” for the research profile amongst DU management and other core staff, as well as the slowness in vertically integrating research in MDA with the educational programs more broadly. While the former feedback further stimulated MDA in linking up with INFORMS, the latter was outside the reach of MDA and was left unaddressed for several years.

Figure 3: Distribution of accumulated research funding (in millions of SEK) per faculty member in the research profile from 2011-2015.

From 2009 to 2015, the research profiles that included MDA had submitted roughly 175 external research applications almost exclusively to funders in the Mode 2 logic. The applications for funding in the five years from 2011-2015 amounted to approx. 600 million SEK, of which some 100 million SEK was granted. Figure 3 shows the distribution of received funding per faculty member. The division of labor stipulated that research funding relied on the supervisory group acting as principal investigator for the proposals. Consequently, a minority of the faculty attracted research funding although research was executed by a larger group of the faculty and PhD students. Internal funds were quite limited and used for co-funding external projects and other forms of seed money to initiate externally-funded research. This principle had repeatedly been discussed in the supervisory group and been found to be the only viable means for ensuring a sustainable research environment justifying educational commitments.
The production of doctorates in the PhD program in MDA prompted the need for an accountable faculty as well as career opportunities for the doctorates. In 2016, the dean suggested the promotion of senior faculty in the MDA research profile to full professorship in MDA. The five members: Kenneth Carling, Mark Dougherty, Johan Håkansson, Niklas Rudholm, and Lars Rönnegård responded to the suggestion and were reviewed by a mixed panel, composed of Christer Carlsson, Jan-Eric Nilsson (Professor of Transportation at KTH), and Athena Vakali (Professor of Computer Science at Aristotle University of Thessaloniki). The panel was highly discordant in their expert reports. Nilsson required deep, demonstrated research skills and educational experience in all domains of MDA, whereas Carlsson and Vakali recognized the collaborative virtue of the transdisciplinary MDA thereby requiring broad knowledge in MDA with depth in subdomains. The promotion process ended with Carling and Dougherty being appointed to full professors in MDA.15

The promotion process and discordance of the reports was thoroughly discussed in the supervisory group and it was concluded that extrapolating Nilsson’s view to the assessment of doctoral candidates and for faculty positions at DU would be unreasonable in relation to criteria applied for academic positions elsewhere. To guide external reviewers for future assessments in MDA, the dean supported the consensus of the supervisory group in producing a guiding document to be used in appointing new faculty members, which came into effect as of 2017.16

The educational plans for PhD, master’s, and undergraduate students in MDA, as well as the assessment criteria stipulate some specific knowledge and skills needed for effective learning, problem-solving, and dialoguing in forums with peers and collaborators. These fundamentals are in formal sciences, such as mathematics, statistics, computer science, and decision theory with an emphasis on “knowing-how”. The form of reasoning in these traditions differs and includes both deduction, induction, and abduction. Intellectually, the student is expected to possess the knowledge and skills to make an unbiased choice of reasoning strategy, whence confronted with a problem, as illustrated by a local learning outcome for the PhD students: “…develop hybrid approaches that combine quantitative and qualitative methods and

15 Later, Johan Håkansson was also promoted to full professor in MDA and Moudud Alam was promoted to associate professor in MDA in 2017. In 2019, an open call for full professorship in MDA led to the recruitment of Arend Hintze and Yves Rybarczyk as full professors in MDA.
16 Specific Bases of Assessment in the Field of Microdata Analysis for Qualification as Professor (including Adjunct Professor and Visiting Professor), Associate Professor, Senior Lecturer, Associate Senior Lecturer and Postdoc, 2017-05-04.
techniques to solve various problems”. Furthermore, relating Wickson et al. (2006) “The founding idea here is that society is facing problems manifest in the real world that are complex, multidimensional and not confined by the boundaries of a single disciplinary framework. TD research is then characterized by its willingness to engage with these types of societal problems.” (p. 1048). This highlights a requirement on the part of the candidate for an open mindedness and willingness to engage in various areas of investigation.

An example of such a problem was the challenge presented in a call by ERA-NET on urban/last-mile logistics where the problem-owner, as member states of EU, had identified poor profitability amongst logistic companies, poor working conditions, and high CO2-emissions in the wake of growing e-commerce. The solution promised (i) increased cost efficiency of parcel delivery companies by means of a higher proportion of first-time delivery success, faster access to (un)loading zones and better management of reverse logistics, (ii) greater adoption of flexible time and place handovers of parcels leading to customer satisfaction, and (iii) societal benefits in reductions in emissions in urban areas, less congestion and less stressful working conditions for employees of parcel delivery companies. To achieve these goals, customer and worker preferences were learnt by abductive methods, transportation behavior by inductive reasoning, and improvements by deductive reasoning. The project started in the fall of 2016 and in an extended version is still ongoing, albeit with new funders, as the solutions were transferable to neighboring problems and other problem-owners.

Was the result of this SAILOR-project, as it is known, good quality research? Wickson et al. (2006) discuss the issue of research quality assurance in transdisciplinary research, similar to that carried out in MDA. The issue is still debated, but Wickson et al. (2006) propose six criteria for assessment:

1. Responsive goals—in TD research, the scholar defines goals through ongoing consultation with the problem context and stakeholders. Goals may therefore not be clear from the outset and may shift in response to developments over the course of the project.
2. Broad preparation—in TD research, ‘adequate preparation’ would require accessing and integrating literature and theory across a broad range of disciplines, as well as engaging with the problem in its broader context.

3. Evolving methodology—an ‘appropriate method’ for TD research is ideally epistemologically integrative and capable of evolving in response to a changing research context.

4. Significant outcome—the outcome of TD research should contribute to the solution of a manifest problem in a way that is capable of satisfying multiple agendas, for example, be concurrently socially robust, environmentally sustainable and economically viable.

5. Effective communication—in support of collaborative processes, TD research should initiate and maintain two-way communication with stakeholders over the life of the project.

6. Communal reflection—in addition to personal reflection, TD research should include a more communal reflective process—multiple disciplinary and stakeholder perspectives informing and transforming each other throughout the life of the project.

To assure quality, the research funder before granting the project verifies that the criteria are integrated in the work plan of the project and verifies their fulfillment in a post evaluation. Therefore, an intellectual enhancement of MDA is achieved whence the faculty improves collectively with regard to the criteria generically, as well as in a specific context. And the operational check of the intellectual level of MDA is investigated by the competitiveness in research calls and the scholarly interest in the disseminated solutions.

In 2019, “Dalarnas villa” was inaugurated. It is a single-family house between Falun and Borlänge purported to be smart and energy efficient, among other things. It is also equipped with multiple sensors, a fact that has prompted a collaborative interest between researchers in the research profile “Energy and Built Environments” and MDA. Several master’s theses and a couple of joint PhD programs have arisen concerning Intelligent Building Management Systems which provoke interesting research problems and computational challenges for MDA on multi-agent systems. Further on intelligent building systems, both individually and collectively, it should be noted that these are sociotechnical systems, that is to say, there exists both physical and human elements that need to be addressed when trying to realistically solve such problems relating to, for example, sustainability. The dual nature of this complex problem (physical-human) highlights the need for a hybrid solution and thus a TD approach is needed putting at the heart the duality that begs an answer to the question: model-based or model-free?

After several years of collaboration in MDA in research projects and education, the research culture had gradually transformed from interdisciplinary to transdisciplinary. This
transformation had not fully impacted the educational plans as indicated by students’ reviews. They reported that the programs were not holistic with regard to learning outcomes. In the spring of 2018, all programs were thoroughly reviewed and restructured in the transdisciplinary logic in an all-faculty effort. The intellectual progress in MDA was manifested by the ease with which this highly complex accomplishment was achieved.

An almost insurmountable difficulty in implementing and advancing the PhD program had been that the operational decisions on the PhD students studies rested with the Doctoral Programs Board which had no competency in MDA. Consequently, administrative decisions were often stalled or awkward in relation to steering the program towards the learning outcomes. In 2019, most operational decisions were decentralized to the Doctoral Program Committee in MDA, composed of supervisors competent in MDA, whereby the program operations could be aligned with the standards of MDA and its quality assurance and, moreover, effectively disseminated in understandable language amongst the supervisors. This reform also simplified the training of co-supervisors in appropriate and relevant supervising techniques in MDA.

At the end of this account, DU had six appointed full professors in MDA. They have reviewed the current status of MDA and initiated a discussion about the future. They purport to combine the research agenda of MDA with that of INFORMS, expressed in the following goals:

1. Extend the scope of the PhD program and Master’s programs with computational AI, possibly offering a specialization in AI as a Master’s program.
2. In consideration of the close relationship between machine learning and human learning, it is suggested to focus research more on learning in collaboration with Educational Science. This could extend further to topics on humans’ machine understanding and vice versa.
3. Increased visibility of MDA including the establishment of a regional virtual warehouse of research data.
4. Extended research collaboration within DU by bringing the MDA technologies to Health and Engineering applications. Possibly, Digital Humanities could offer a cross-cutting research program within DU.
5. Consider addressing the challenge of formal training of PhDs concurrently employed by industrial research institutes and non-research oriented universities in, e.g., South-America.

18 "This is a response from the full professors of Micro Data Analysis (MDA) to the draft of strategy as of August 20, 2019", 2019-09-22
Certainly, the initial goals of this paper could jointly serve for further collegial discussions and the formation of an action plan for MDA in the not-too-distant future.

6. Concluding reflections

I end this paper with some personal views and reflections. The collegial environment sharing enthusiasm for applied and problem-solving focused research has been stimulating and gratifying. The openness to transdisciplinarity was invigorating and I have never felt an urge for labelling the research and educational activities I and colleagues have opted for. I believe a labelling bear no scientific value. Arguably, however, a label is needed for communication and university bureaucracy. All in all, I found Microdata Analysis to be a good label. Central to the scientific activity is data, and these are expected to be on an atomic level because the greatest possible detailedness is the scope. The flipside of micro is the skill to manage gigantic data quantities. Analysis as the microdata should be subject to knowledge extraction. MDA is a normative discipline as it aims to solve real-world problems and steer context-specific decisions and action. Regrettably, I think the MDA-label poorly communicates the normativity.

A researcher belongs to a research community in which a particular terminology and certain norms apply. An environment aiming to attain transdisciplinarity should give due importance to learn a broad set of terminology and cultivate a minimum set of norms. Traditional disciplines are likely to be provoked by these two aims. I think it is important for such an environment to avoid defining its boundaries whereas defining its core is helpful. A practical way of defining the core is in terms of the syllabuses for mandatory PhD-courses.

Transdisciplinarity implies a non-static environment which makes peer-reviewing difficult in practice with consequent challenges to achieve quality assurance. I believe an accountable and opened supervisor group to be imperative. Such group needs to repeatedly discuss by whom the knowledge production shall be recognized. Gobet (2017) relates the pedagogical emphasis on Knowing-that versus Knowing-how where the latter focus on training usable skills. I believe a transdisciplinary environment should focus on Knowing-how as skills and problem-solving is more amenable to direct testing and clear feedback. Quality assurance can thereby be achieved by benchmarking solution-strategies to existing and competing strategies.
Obviously, by time a transdisciplinary environment risks fossilization. I put the responsibility to mitigate the risk on the supervisor group that needs to be open to external influences in terms of quality assurance, communities by which it interacts, and problems to be tackled within the environment.

**Acknowledgments**

I recognize the input on previous versions of this paper from Moudud Alam, Mark Dougherty, Hasan Fleyeh, Irene Gilsenan Nordin, Mengjie Han, Arend Hintze, Asif M Huq, Johan Håkansson, Ross May, Roger G Nyberg, Lars Rönnegård, Yves Rybarczyk, Thomas Sedelius, William Song, Jonas Tosteby, Jerker Westin, Siril Yella and Dick Åhman.

**References**


