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# Epistemological, Artefactual and Interactional–Institutional Foundations of Social Impact of Academic Research

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**Abstract** Because of the gross difficulties in measuring the societal impact of academic research, qualitative approaches have been developed in the last decade mostly based on forms of interaction between university and other societal stakeholders. In this paper, we suggest a framework for qualitative analysis based on the distinction between three dimensions of societal impact: epistemological, artefactual and interactive-institutional. The epistemological dimension addresses what new research results and understanding of relevant phenomena have contributed to solving of technological and societal problems. The artefactual dimension comprises analysis of the artefacts, methods, tools and services through the use of which societal impact is realized. Finally, in the interactional–institutional dimension the forms and forums of collaboration between university and other societal actors are explored. The model is elaborated by analyzing the work of three university research groups in different disciplines. The framework may be used in articulating formative and dialogical peer evaluation of research to foster learning and social improvement as well as in evaluation of research proposals and research programs.

**Keywords** Science–society interaction · Impact of academic research on society · Disciplinary patterns of interaction

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## Introduction

Academic research evaluation has seen important changes in the 2000s. These are related to changes in the societal role of university and transformation of university governance towards increased social accountability and auditing. The traditional research assessment was based on peer review and, subsequently, the number of publications and citation indexes. In the 1990s, the demand for measuring economic returns from research funding increased and it was closely associated with advancement of technology transfer and commercialization of university research results. In the 2000s, the EU and its member states started to develop frameworks for analyzing wider societal impacts of academic research, a task that was related to the introduction of the so-called third mission of universities. Thus, the focus in the impact assessment shifted to the development of systems of indicators through which the societal impact of research could be measured and used in allocating public funds for research (Kearnes and Wienroth 2011; Bornmann 2013). At the same time, however, qualitative approaches, such as the payback framework (Donovan and Hanney 2011; Klauzer et al. 2011) or productive interactions (Spaapen and van Drooge 2011) started sprouting. In this paper, a novel framework for qualitatively analyzing the societal impact of university research will be suggested with empirical illustration coming from three different research areas.

The attempt to administratively manage research impact has been criticized. Martin (2011), for example, expressed the fear that further development of the impact evaluation systems encompasses a risk of growing into a very expensive "monster" with limited practical utility when compared to costs of running the system. Many other observers have claimed that the creation of a unitary system of impact assessment may not be a realistic enterprise as it would easily gloss over disciplinary differences. Concerns have been raised about the complexity of the concept of impact and about the fact that in practice it has become defined in terms of lists of indicators with limited connection to the theoretical or historical research on science–society interaction. Finally, there has been a tendency to see the third mission activities as separate tasks from the epistemic mission of academic research, i.e. an attempt to increase our understanding of the world, which plays a central role in enabling the solving of technical and societal problems of various kinds.

In this paper, we agree with the thesis that there is a "relevance gap" in the evaluation of academic research (Nightingale and Scott 2007), a condition that underlines the need for developing new concepts and language to describe the relation between academic research, societal problem-solving and development of social practices. What is needed is an analytical framework with whose help one could articulate the role of new scientific understanding in solving societal problems of various kinds. Such an understanding would orient and enable practical problem-solving and thus enrich our understanding of the world around us. In this paper, we will outline an approach to analyze societal impact of research that is based on a distinction between three dimensions of societal impact: (1) epistemological, (2) artefactual and (3) interactional–institutional foundations of impact. We will

illustrate how such an approach can be used to analyze work by three research groups from Finnish universities. The framework illustrated is meant to stimulate self-reflection of research communities so as to help them articulate the societal impact of their research whenever it is needed, e.g. as a part of funding applications and drafting of case examples for evaluation purposes. The framework may be used in extended peer evaluation with different stakeholders and as part of formative evaluation, which seeks to guide learning and practical improvement of research.

*Developments in Addressing Social Impact of University Research*

Measuring research impacts came from attempts by economists to better understand economic growth and productivity (Godin and Doré 2005). Research and development indicators were integrated into economic models to estimate the return rate public or private sector actors could expect from the investment in science and technology. As any attempt to understand the social impact of research in purely economic terms misses important parts of the picture (Molas-Gallart et al. 2002; Kearnes and Wienroth 2011; Bozeman and Sarewitz 2011; Bornmann 2013; Jacobsson et al. 2014), the impact assessment has been expanded to include non-economic impact of science. Much of the literature that has emerged since the turn of the millennium was commissioned by policymakers and aimed at contributing to national science and technology policy discussions (Molas-Gallart et al. 2002; Reeves 2002; Allen Consulting 2005; LSE Public Policy Group 2008; Abreu et al. 2009; PACEC/CBR 2010; Hughes et al. 2011).

Regarding the quantitative approach to understand science's social impact, researchers have often mapped the phenomenon on the basis of typologies of knowledge exchange mechanisms. Godin and Doré (2005), for example, provided a list of 11 categories of impact, each of which consisted of several subcategories. Among the major categories were economy, culture, society, policy, health and environment. Hughes et al. (2011: 17) distinguished four main knowledge exchange activities – commercialization, people-based, problem-solving and community-driven activities – each of which was further divided into more specific types of interaction modes, the relative importance of which was also assessed. The two most important interactions in commercialization were running consultancy and forming of a spin-out company, in people-based activities attending conferences and participating in networks, in problem-solving activities giving informal advice and providing consultancy services; and in community-driven activities delivering lectures and conducting school projects.

According to Martin (2011: 250), the linear idea is indeed embedded in the very concept of impact as it encourages us to conceptualize impact from the point of view of "how knowledge from an individual piece of research is subsequently taken up and used". This is the case in studies that utilize the research-use scale developed by Knott and Wildavsky (1980; also Landry et al. 2001a, b; Davies and Nutley 2008; Molas-Gallart 2014). A similar conclusion can be drawn about policy-oriented reports that seek to help researchers to argue how they contribute to society. A case in point is a handbook by LSE Public Policy Group (2011: 12–13), which claims that research has "an external impact when an auditable or recorded

influence is achieved upon a non-academic organization or actor in a sector outside the university sector itself." Although the handbook notes that "ideas hardly ever travel on a linear path from A to B" (Ibid.: 149), the process is nonetheless described in the form of a linear chain of effects that flow from academic research to wider society. In between these two extreme poles there exist joint-up scholarship and intermediaries of various kinds that simplify, re-process and rearrange scientific ideas so as to communicate them more effectively (Fig. 1).

Several authors (Bornmann 2013; Molas-Gallart and Tang 2007; Donovan 2011; Spaapen and van Drooge 2011; Bell et al. 2011) have summarized the limitations of quantitative approaches by saying that they capture the phenomenon in terms of quantifiable, abstract variables and relatively linear streams of effects. Due to these problems, the same scholars have increasingly underlined the need for developing qualitative (Allen Consulting 2005; Molas-Gallart and Tang 2007; Kearnes and Wienroth 2011; Bell et al. 2011; Spaapen and van Drooge 2011; Bornmann 2013; Molas-Gallart 2014; de Jong et al. 2014) or mixed-methods approaches (Meagher et al. 2008; Donovan 2011; Klautzer et al. 2011) to address the topic. The current turn towards qualitative approaches in impact assessment has not been limited to research evaluation studies but has also been emphasized by the research evaluation practices of the UK. In the recent Research Excellence Framework, 6,975 impact case studies were conducted and evaluated by more than 1,000 assessment panel members from academic and societal interest groups.

As achieving societal impact is usually regarded as uncertain, complex and long-term, the focus in research has shifted away from addressing impacts *per se* to the processes through which impacts are generated. Spaapen and van Drooge (2011; also Molas-Gallart and Tang 2011; de Jong et al. 2014), for example, have emphasized "productive interactions" defined as "exchanges between researchers and stakeholders in which knowledge is produced and valued that is both

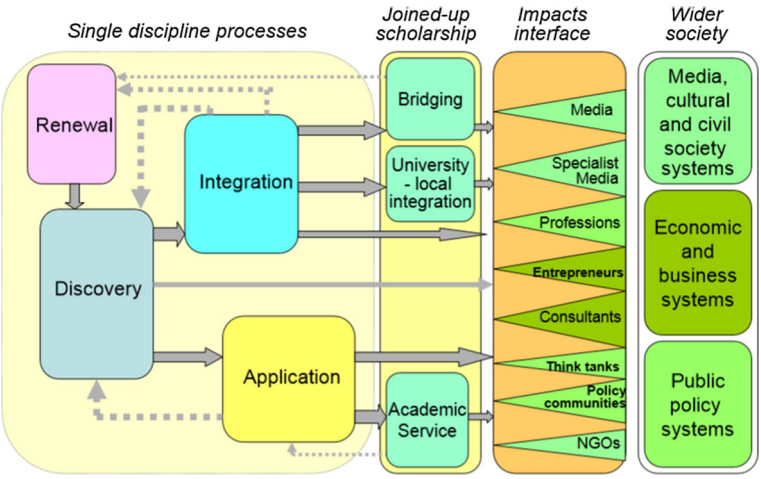


**Fig. 1** The origins and patterning of external impact of academic research as represented in *Maximizing the Impacts of Your Research: A Handbook for Social Scientists* (LSE Public Policy Group 2011: 151)

scientifically robust and socially relevant" (Spaapen and van Drooge 2011: 212). The interaction is considered productive "when it leads to efforts by stakeholders to somehow use or apply research results" (Ibid.: 212). According to Spaapen and van Drooge, productive interactions can be seen as an iterative process of knowledge creation between scientists and societal stakeholders. The concept thus has affinities to Mode 2 knowledge which is produced in "agora" (Nowotny et al. 2001: Ch. 13) and the concept of co-production of science and social order (Jasanoff 2004). Both these concepts encourage us to see how science as a social practice becomes intertwined with actors and organizations traditionally seen as extra-scientific. They adopt the constructivist concept of scientific practice, which ends up blurring the boundaries between science, technology and policy. In his essay "Give me a laboratory and I will raise the world," Latour (1983: 141) referred to Knorr-Cetina (1981) and recapitulated the main achievement of the constructivist studies of science: "The result, to summarize it in one sentence, was that nothing extraordinary or nothing 'scientific' was happening inside the sacred walls of these temples." The idea was further elaborated by Callon et al. (1986: 4) who stated that their central methodological prescription was "to follow the actors both as they transform society and as they seek to build scientific knowledge or technological systems." The argument follows Latour's by stating "that science is politics by other means and, accordingly, that the study of science takes us straight into politics" (Ibid.).

In our view, the above-mentioned analytical integration of different societal spheres hampers the analysis of science–society interaction as the specificity and complementarity of contributions by various actors remains hidden. We think that academic research needs to be analyzed as an activity, the function of which is to produce and accumulate scientific knowledge by following certain, historically-developed methodological norms. This is connected to the task of the university to systematically increase and transmit disciplinary knowledge. As Fuller (2010: 301) points out, the university can be seen as "a proactive universalizing agent explicitly dedicated to manufacturing public knowledge as a public good. The university's mission to translate research into teaching is the key. (…) New discoveries and inventions are incorporated into a regularly reproduced body of collective knowledge, as represented by the curriculum." Following Mertonian functionalism, foundations of this mission and the related norms of science have been analyzed in terms of Luhmann's systems theory (Stichweh 1996), neo-institutionalism (Elzinga 1997) and constructivism (Tuunainen and Knuuttila 2008). Corresponding to these views, we think that the specific contribution of science in dealing with societal problems is to provide understanding of related relevant phenomena. That is why we think that in evaluating the societal impact of research an exclusive focus on interaction *per se* hides the specific contribution of science embedded in scholarly science.

At this point, the idea about the connection of science to societal problem-solving articulated by finalization theory (Krohn and van den Daele 1998) is valuable. We agree with it as we agree with Leeming (1997) who claims that due to the heterogeneity of science, a unified theory of cognitive development of scientific disciplines originally suggested by the finalization theory seems impossible. The

interaction between theoretical work and societal problem-solving is constant and adopts various forms in different disciplines, in different moments of time and even in different national contexts. That is why we think that a proper unit of analysis for understanding science's impact on society is an academic research group and its program. To avoid short-termism often characteristic to research evaluation, the work of research groups needs to be followed for more than a decade; the accumulation of research results, theoretical generalization based on them and transforming the results into forms that are usable outside the research community takes time and effort, and must be preserved by the analysis.

*Analytical Framework, Research Questions and Data*

Drawing from the idea of disunity of science (Galison and Stump 1996) we will maintain that science is a heterogeneous social activity where different disciplines possess dissimilar methodologies, ontologies and forms of interaction with society. To develop a framework for studying the social impact of research, we have selected three research groups that exemplify different types of science from literature: entrepreneurial (Etzkowitz 1998), policy relevant (Jasanoff 1987) and public good (or welfare-service-related) science (Radder 2010). The first of these groups, which focused on the development of a virus-resistant transgenic potato, represents entrepreneurial science where the societal impact was realized through commercialization of research results. The second research group – urban geography – represents policy relevant science and provided municipal policymakers and urban planners with knowledge about the segregation processes in urban areas. Finally, the third research group represented welfare-related research. It addressed learning difficulties in children and worked extensively with public service providers, teachers and school psychologists. The latter two research groups can be jointly described as being instances of public interest science, which differs from autonomous academic research by the fact that they incorporate social goals in their agendas, and from commodified science by embracing a broader range of social goals than economic ones only (Radder 2010: 18). In what follows, we will analyze the ways in which these three research groups contributed to society by drawing a distinction between epistemological, artefactual and interactional–institutional foundations of impact. Our research questions follow this tri-partite distinction:

1) What new understanding of phenomena related to a societal or technological problem did the studied groups' research provide?

In our view, both epistemic concerns of science and motives related to society and its problems influence the direction of research. Philosophers have called this double determination of scientific knowledge (Niiniluoto 2002). Due to scientification of technology (Böhme et al. 1983) and the complexity of social and ecological problems, better understanding of phenomena behind different kinds of societal problems is increasingly needed. It is evident that societal concerns influence the ways in which research problems are formulated in academia. To understand the specific role of science in society, we find it important to pay

attention to the conceptual understanding provided by research, with the help of which academics contribute to the solving of societal problems.

2) Through which kinds of artefacts, instruments and services is the impact of science on society materialized?

Already in the 1980s, de Solla Price (1984) suggested that technological artefacts and instruments constitute a bridge between science, technology and industry. Procedures, tools and methods developed in research can be used in industry and in producing societal services. Researchers and clinicians share tools in medicine, and software developed for research purposes can be used in other society sectors. The Internet that was originally developed to foster communication between university researchers is a prominent example of this. As technology, it has contributed to the development of new tools of collaboration and information exchange, a phenomenon that has been analyzed in the context of technological platforms (Keating and Cambrosio 2003).

3) What kinds of social and organizational forms do the interaction between researchers and societal stakeholders take?

It is widely recognized that university researchers are collaborating more with different kinds of societal actors. The organizational forms of these partnerships are historically changing. In actor-network theory (Latour 1987), the emergence of facts and disciplines imply the institutionalization of techno-economic networks that make the distribution of facts and methods possible across organizational boundaries. From this point of view, the impact of science on society can be analyzed in terms of emergent collaborative networks, the ways in which they are organized and the extent to which they become institutionalized. Very interesting are the changes in the institutionalized forms of collaboration and the new fora and means of transferring research knowledge using the Internet.

To address the above-mentioned research questions, and to illustrate the tripartite analytical framework developed, work by three research groups will be presented. The data on which the analysis is based consists of interviews with researchers and stakeholders and various kinds of documents, such as scientific publications, reports, theses, administrative documents, web pages and news items in the media. We analyzed the data, paying attention to the three dimensions described above. We focused on the epistemic work done by the researchers so as to illustrate the way in which the group contributed to the emergence of innovative products, influenced political decision-making or supported development of public services. We also analyzed how these results materialized into artefacts that could be transferred from one place to another and examined how collaboration networks between researchers and societal actors contributed to the realization of the social impact of research.

The three research groups had defined their research agendas and problems independently of any strategic national research programs. They had applied and received funding for their work from two main funding sources in Finland, the Academy of Finland and TEKES (Finnish Funding Agency for Innovation) and various foundations.

*Uncovering Mechanisms of Virus Resistance and Construction of a Virus-Resistant Potato*

The research group led by Professor Eija Pehu worked in plant production at the University of Helsinki, Finland. Originally, it studied biological hazards in potato production created by viruses and later included in its program also insect resistance in crop plants and cold tolerance in potato and oat improvement. The epistemic agenda of the group focused on the diversity of the resistance to viruses found in a wild potato species and especially on the genetics of its virus-resistance mechanism. Although the agricultural usefulness of the research results was a central motivating factor behind the study, the materialization of this aim pre-required construction of new theoretical knowledge. As one researcher (Valkonen 1991: 28) pointed out: "In order to succeed in altering the characteristics of the potato in the way we desire, we need as rigorous understanding of the vital functions of the potato, and their regulation, as possible, that is, basic plant scientific research."

The group thus characterized the virus resistance trait in the wild potato and attempted to transfer its virus-resistance genes to the cultivated potato. The experiments to create a new kind of a transgenic potato failed, however, and the group's first research approach to combat viral diseases was stymied (Tuunainen 2001). To materialize its aim, a new approach where a gene from a potato virus was used as a source of virus resistance was soon adopted. The idea of using a specific gene of the potato virus Y, called P1, to mediate virus resistance emerged as the group heard about unpublished experimental results from Cornell University where virus-resistant tobacco had been produced by introducing a viral gene into the plant. Inspired by this result, the group decided to experiment with transforming the cultivated potato with the viral gene P1, as it was similar to the one used in Cornell.

The experiment, conducted in 1993, proved successful and brought about a new artefact, a transgenic potato with an increased resistance to viruses. As the emergent virus-resistance phenomenon in the potato was novel, it became an interesting topic for further theoretical research, thus transforming the group's epistemic agenda. The researchers subsequently showed that the resistance mechanism was an example of a new phenomenon called gene silencing.[1] As a result of this, the group's work differentiated into two separate but interconnected lines: one focusing on understanding the genetically-engineered virus resistance mechanism and the other on using the viral gene in breeding for resistance (Tuunainen 2001).

The artefact, i.e. the model system for virus resistance in plants (a genetically modified Pito potato), was patented in the U.S. in 1994. Soon after this, the group altered its collaboration network so as to find a partner with whom it could develop a commercial product from the invention. It joined forces with a Danish plant breeding enterprise, DLF Trifolium, which had the necessary competence in plant genetic transformation and plant-breeder's rights for the entire downstream process through which the patented invention could be transferred to the market (Tuunainen 2002).

[1] Gene silencing refers to a process where proteins and RNAs produced by transgenes become chemically decomposed in plants transformed with so-called non-structural viral genes.

The joint work with DLF involved further investigation of the virus resistance in the potato and developing commercial potatoes with an enhanced resistance trait. The dual focus of the group on epistemic and applied objectives thus continued during the industrial collaboration. The theoretical problems related to the resistance mechanism were addressed at the university while the development of commercially viable potatoes took place in cooperation with DLF. The creation of commercial potato varieties contributed to the understanding of the virus-resistance mechanism, however, by providing data to support the hypothesis according to which the mechanism behind the resistance phenomenon was indeed gene silencing. More specifically, DLF found out that if two particular gene sequences were integrated in a transgenic potato, they tended to produce molecules that acted as signals to initiate the silencing mechanism. This observation was epistemically interesting but also applicable in breeding: modifying plants to produce such signaling molecules would start the silencing mechanism and respective resistance effect (Tuunainen 2002).

Successful as it was, the joint work came to an end before the commercial potato variety fully materialized. The main reason was the EC's moratorium on growing transgenic plants, an act that destroyed markets of transgenic plants in Europe. Due to this, DLF gave up breeding transgenic potatoes, a decision that brought the collaboration to an end. Despite this, development of commercial products by the group continued: it established a spin-off company to make use of other results it had achieved, i.e. the improvement of turnip rape feed quality and a system for producing medical and industrial proteins in plants. For 2 years, the group's epistemic work and business activities were pursued together after which it became a fully-fledged private enterprise (Tuunainen 2005).

### *Monitoring Urban Stratification Process and Providing Knowledge for Policymakers*

The epistemic agenda pursued by Professors Mari Vaattovaara and Matti Kortteinen of the University of Helsinki (called hereafter the professors) addressed the change of urban structure in the greater Helsinki metropolitan area with special focus on the social differentiation of the previously uniform city. The egalitarian social policy of the post-WW2 era had diminished the city's division into poor and well-off areas, a condition which began to deteriorate after the economic crisis of the 1990s. Consequently, a fear of urban decay arose among politicians, administrators and observers, and was expressed in public media.

Research on the effects of the economic depression began at the City of Helsinki's Urban Facts Department, where Vaattovaara worked as a researcher in the 1990s. Using factor analysis and geographic information systems, she found out that the population in Helsinki lived in three distinct residential conditions: middle-class families in owner-occupied houses, low-income and unemployed residents in rented housing and wealthy people in spacious living conditions. According to the results, no deprived neighborhoods existed, but the poor were scattered in a mosaic-like manner in different areas, forming what were called pockets of poverty (Vaattovaara 1998).

As other studies soon confirmed, these pockets began to cluster around each other, contributing to the increasing social segregation of the city structure: the favorable societal development had turned into growing social, economic and spatial stratification (Kortteinen and Vaattovaara 1999). Although the change was slow and concentrated on small areas, the eastern part of the city was in danger of falling into a vicious circle of underdevelopment: socio-economic deterioration and the district's declining attractiveness as a residential area were feeding each other and leading to accumulating levels of social and economic disadvantageousness (Kortteinen and Vaattovaara 2000). To better understand this development, the professors investigated specific phenomena, such as immigration, unemployment and crime in different city regions to see how they were related to the segregation process. The epistemic picture was then completed by analyzing those districts that were better off to understand the flip side of the segregation, i.e. the ways in which the city's wealthy population evaded the poor districts (Kortteinen et al. 2005). The achieved results created an obligation for the researchers to actively participate in the public discussion about the reasons for segregation and the ways in which it could be combatted.

Epistemologically, the professors used the case of Helsinki to further refine the polarization thesis, i.e. the socio-economic polarization of the modern, globalized city presented by Sassen (1991). Instead of such a bipolar development, the professors distinguished between three types of residential areas: (1) new elite areas of well-educated people, (2) poor areas with a non-working population and (3) an intermediate grey zone between the two. Furthermore, they claimed that economic resources were not a sufficient explanation for the changes in urban structures, but cultural differences had to be taken into account: parentage and education affected the inhabitants' housing preferences and made the segregation a self-feeding social process (Kortteinen et al. 2005; Vaattovaara 2011).

Based on the results, the professors made a series of efforts to contribute to the public policy discussions in different contexts. The major types of the interactional fora were as follows:

1) Discussions in daily newspapers;
2) Advisory committees and working groups nominated by the Finnish government or regional administrative bodies;
3) Unofficial discussions between the professors and national and regional policymakers;
4) Policy-oriented professional seminars organized by the cities; and
5) Internet-mediated discussions.

As regards newspapers, the professors' results were extensively discussed in *Helsingin Sanomat*, the main daily newspaper of Finland. During 1995–2013, it published 66 news items, opinion articles and editorials related to urban segregation by researchers, civil servants, politicians and journalists. Out of those 66 articles the professors were quoted or referred to in 33, including their own comments and comments by researchers working in their group. The 50% share of the published

articles shows that the research results played a central role in stimulating the public debate on the topic.

Of the other interactional fora, we will next concentrate on the policy-oriented seminars and Internet-mediated discussions. An example of the former was a seminar organized in January 2012 by the City Council of Espoo, the second largest municipality in Finland, to discuss changes in the municipal structure of the Helsinki area. On this occasion, Vaattovaara summarized the research results and commented on alternatives for the area's municipal structure maintaining that administration should be placed close to the inhabitants who lived in differentiated urban environments. She suggested that a solution to the issue should be crafted through deliberative democracy. These recommendations were in line with earlier claims by the professors according to which the problems caused by metropolization could not be solved by creating large-scale municipalities or developing regional governmental bodies, as was suggested but required networked cooperation and policy coordination among the municipalities (Vaattovaara and Kortteinen 2011). In the seminar, all councilors were of the same opinion about the right way forward.

Regarding the Internet-mediated discussions, two major types can be distinguished: (1) discussions about news pieces where the professors' results were reported and (2) weblogs of policymakers who mobilized the professors' results as a part of their political activities. Of these, the latter was of central importance to the social impact of research and is discussed here.

A case in point is a weblog by a member of the Finnish parliament, Osmo Soininvaara, who acted as vice-chairman of the Helsinki City Planning Department and member of the Helsinki City Council. In August 2012, Soininvaara wrote an entry in which he referred to a presentation by the professors in the Uusimaa Regional Council where they gave their expert opinion about the draft of the Uusimaa regional plan. Soininvaara participated in the meeting and used the information he received in his blog entry. Referring to the studies by the professors, he noted that social segregation has increased and immigrants tended to concentrate in certain areas of Helsinki, creating a risk of "white flight" – a phenomenon where the wealthy native population moves out from an area if the share of immigrants rises above a certain critical limit. According to him, a major catalyst for white flight in Helsinki was the quality of schools, as many people chose their neighborhood on the basis of the schools available for their children. He concluded that the results did not support unlimited social mixing in housing, as the highest and lowest social classes did not socialize with each other. He found it more realistic to mix poor and middle-income people and middle-income and wealthy people. Following the professors, he also suggested that social housing should be placed in good neighborhoods where it tended to produce fewer problems than in poor areas.

Soininvaara's weblog is an example of a technically-mediated interactive forum read and commented on by many who held key positions in politics. The blog entry received 87 comments, 40 of which addressed possible solutions to the segregation problem. Many of these urged Soininvaara to specify some aspects of his proposals or offered further viewpoints concerning the suggested policy measures. As other politicians and officials of the Helsinki City Planning Department read the blog and participated in the discussion, it can be assumed that the issues raised by

Soininvaara received due consideration by those involved in their management. For Soininvaara himself, the weblog acted as a medium through which he was able to receive a lot of new information related to issues relevant in urban policymaking.

*Solving the Problems of Reading and Writing Difficulties*

The third research group, led by Professor Heikki Lyytinen of the University of Jyväskylä, Finland, concentrated on research in learning difficulties and tools to alleviate problems created by them. In the knowledge economy, literacy is a key capability of citizens and constitutes a foundation for success in schooling and life-long learning. Strategic literacy, i.e. the capability of an individual to follow, evaluate and utilize new knowledge forms a foundation for innovation and absorptive capacity in firms and other organizations (Miettinen 2013). Since the societal significance of education has increased, early problems of reading and writing may lead to the exclusion of an individual from secondary education and labor markets (Esping-Andersen 2009). The experiences of the 9-year comprehensive school in Finland have demonstrated that the early recognition of reading and writing difficulties, and immediate measures to solve them, are instrumental for success in school attendance.

Concerning this broad area, Lyytinen's group focused on increasing understanding of and combatting effects created by dyslexia. This was done in collaboration with the Niilo Mäki Institute (NMI), which is a multidisciplinary research and development unit actively engaged with the surrounding society, including the school system. Five institutionalized forms of this interaction can be distinguished:

1) NMI maintained the Child Research and Consultation Clinic together with the Child and Family Counseling Unit of the City of Jyväskylä;
2) It developed diagnostic tests for learning in reading and mathematics, and remedial tools together with schools;
3) It provided diagnostic tests, learning games, material packages and textbooks to schools, special education teachers and psychologists;
4) It contributed to further education of teachers, special education teachers and school psychologists; and
5) It published the NMI Bulletin, a peer-reviewed journal on learning difficulties largely read by school personnel involved in special education and student welfare.

In 1993, as the Lyytinen group was nominated as a center of excellence in research by the Academy of Finland, it initiated a longitudinal study on children's sensory, motor, cognitive, and language development with the main focus being on language development (Lyytinen et al. 2001). Until 2011, the development of 200 children with and without familial risk of dyslexia was followed from their birth until school age. The goals of the research were epistemic and practical. The researchers aimed to (1) understand the nature of dyslexia by defining its precursors, (2) define the criteria and create the means to identify children at risk and (3) develop preventive training tools to overcome the consequences of dyslexia (Lyytinen et al. 2009). The hypothesis of the study was based on phonological core

deficit theory, according to which a speech perception deficit was viewed as a precursor of dyslexia.

The research contributed to the understanding of the genetic origins of dyslexia. Familial risk of dyslexia proved to be a strong predictor of later difficulties in reading: a child with familial risk would face reading difficulties four times more often than a child without such risk. According to the group, the best cognitive precursors of dyslexia were phonological sensitivity and letter knowledge, i.e. the ability to construct a connection between a letter and a phoneme, a capability that starts to develop at the age of 3.5 years (Puolakanaho et al. 2007). Very early predictors of pre-reading as well as reading and spelling skills were measured at birth (Leppänen et al. 2010). These results showed that before the environment had had an effect on the child, there were differences in the children's brain functions which might hinder him or her from benefiting from a normal speech environment. Another key finding was the role of different languages in learning. Finnish is a transparent language and there is a symmetrical consistency at the letter-phoneme level. This makes learning to read easy. Since most of the research literature focused on English, which differs greatly from transparent orthographies, the results from the study opened up a new understanding of the barriers of reading acquisition, an outcome significant also from the practical point of view.

Epistemically, the concept of a precursor was central in the study of dyslexia, as it provided a connection between scientific explanations and societal intervention. The lack of phonological sensitivity – an inability of a child to form a connection between a phoneme and a letter – proved to be a central precursor for reading and writing difficulties at the age of five and six. Based on this finding the group developed a remedial computer game, Graphogame, especially designed to meet the needs of dyslexic children who had poor speech perception (Lyytinen et al. 2007). It was first designed to follow the reading acquisition process (Lyytinen et al. 2009), but was later turned into a tool for individually targeted training.

Children with attention difficulties seemed to benefit from the game as it was "attention-catching": the principle of playing was easy to master and the feedback was immediate (Hintikka et al. 2005). A play-like element also motivated children. One feature of the game was its adaptability to the player's skill level, which maintained the player's motivation. The research group described Graphogame's influence as follows:

> The game is available via the Internet (see http://www.lukimat.fi) to children who have parental permission. (…) We believe that children with familial risk and/or low letter knowledge during the few months preceding school entry benefit from preventive playing in terms of avoiding unwanted failure experiences during the early months of school instruction. Therefore, we have recommended to kindergartens where all children in Finland have their preschool year (…) that the game should be used during the last 2 months (…) and preferably with massed practice. This means short 5–15-min periods several times per day for as long as children require to learn the letter-sound connections (…). Today, more than 50,000 children in Finland have tried the game and very few have failed to benefit (Lyytinen et al. 2009: 672).

In 2005–2008, different versions of the game were developed in collaboration with international research partners for Finnish, English, Swiss and Dutch languages. Subsequently, an international network of centers of excellence was established to develop the game's international versions, known as GraphoWorld, and to organize research and training related to its use. In addition, developmental cooperation with African countries, such as Zambia, soon started. The basis for this was favorable as most of the African languages are transparent like Finnish and Graphogame is thus easily transferable to them.

Following the success of Graphogame, a set of Internet-mediated interactional artefacts were created. Among these was the information platform called LukiMat, which provided its users with up-to-date information but worked as an assessment and training environment. The reading section of LukiMat was organized around Graphogame and its different versions. The mathematics section contained a game called Number Race, a learning environment called Neure, and a version of Graphogame, Graphogame-Math. As the basic idea of LukiMat was provision of information and tools free of charge, the platform attracted attention on a national plane. Its biggest user group was teachers who used the games and assessment tools in their work. Also, parents were interested in getting access to training games that could be used at home. In exchange for providing remedial tools for those who needed them, the researchers acquired access to the research data that accumulated over time as children played the games.

## Conclusion

Since the turn of the millennium, the accountability of academic research has extended from evaluation of research excellence and economic contribution of science to wider societal impact of research. Indicators for this have been developed and methods of qualitative evaluation have been introduced, especially in the form of policy-oriented impact case studies. In this connection, serious doubts have been raised about the possibility to successfully account for the social impact of science by extensive systems of indicators and related case information. Martin (2011), for example, has claimed that attempts to develop any formal system of accountability possess the risk of becoming an expensive monster system with limited usefulness in research funding and prioritization. In addition, it remains open what sorts of performativity consequences the indicator systems may have (Nightingale and Scott 2007). The problem with these kinds of approaches is that they easily exclude the contents of research and hardly suffice methods to uncover the specificity of social impact in different disciplines. As noted earlier, the overall impact of academic research is a necessarily multidimensional phenomenon and its realization differs between disciplines, local research programs and national contexts.

A new social contract between science and society increasingly requires universities, academic researchers and research communities to demonstrate the social impact of their research. This is also increasingly required in funding applications. Vocabulary for such a reflection and articulation is urgently needed. This paper suggests that the social impact of academic research can be demonstrated

by describing research activities in terms of their epistemological, artefactual and institutional-interactional dimensions: (1) the epistemological viewpoint concentrates on an increased understanding of the relevant phenomena related to societal problems; (2) the artefactual viewpoint pays attention to the instruments, methods, products or services that are transferred from university to society; and (3) the institutional-interactional dimension concerns the form of collaboration networks and field-specific institutions through which researchers interact with societal actors.

In this paper, we employed this approach and illustrated its usefulness by examining the work by three research groups that represented entrepreneurial, policy-oriented and welfare-service-related research. The research programs investigated were motivated by an attempt to achieve societally important values, such as a virus-resistant crop plant, balanced urban development or alleviating the problems caused by dyslexia. In each case, the materialization of the societal benefits required theoretical understanding of the phenomena related to them: the mechanisms of virus resistance in plants, characteristics and causes of urban segregation process and precursors of dyslexia in children. This is in line with the idea about scientification of technology (Böhme et al. 1983) which creates a situation where demanding technical problems can no longer be resolved by direct practical optimization based on prior experience but require understanding of the related phenomena achieved through scientific research. The plant biotechnologists in our case sought to understand the nature of the virus-resistance phenomenon to develop a virus-resistant potato. The urban researchers analyzed social structures in different neighborhoods and mechanisms of social segregation before they could contribute to policymaking. Finally, the psychologists investigated the genetic and neurological precursors of dyslexia to develop ways to overcome the learning problems.

In Table 1, we summarize the main findings of our study from the point of view of the three dimensions of achieving societal impact. The table shows that the nature artefacts through which the research results were transferred from science to society differed between research areas. In plant biotechnology, the model organism – the patented transgenic potato – was of central importance. In urban studies, publications, expert statements and public presentations were essential. In the research on learning difficulties, diagnostic tests, teaching materials and remedial tools were key artefacts of transmission. Correspondingly, the forms, fora and institutions of science-society interaction differed: In plant biotechnology, collaboration with firms was a predominant form of interaction. In urban studies, the interaction took place with policymakers and urban planners mostly in fora related to regional and municipal policymaking. In the research on reading and writing difficulties, interaction was tied to the school system and ranged from the joint test development and professional further education to the establishment of an Internet platform where issues concerning learning difficulties were addressed.

Regarding the epistemological dimension, interaction between theoretical work and societal concerns had a cyclical rather than a linear pattern in the cases analyzed here. Researchers oscillated between theoretical objectives and societal relevance, and these two motives of research mutually influenced each other. There were periods of time in research when theoretical work dominated. The results achieved gave rise to reorientations in research programs, led to new ideas of possible

**Table 1** Interaction between epistemic and societal problems, mediating artefacts, instruments and services and forms of science–society interaction in the studied research areas

| | Epistemological dimension: understanding of the relevant phenomenon | Artefactual dimension: artefacts, instruments and services through which the impact on society was realized | Institutional-interactional dimension: forms of science-society interaction and researchers' major partners |
|---|---|---|---|
| Research on virus-resistance in potato | Understanding of the virus-resistance phenomenon<br>Development of the transgenic potato revealed a new resistance mechanism, gene silencing | A patented and licensed model plant of a virus-resistant potato<br>Plant material consisting of hybrids between wild and cultivated potatoes | Joint potato breeding research with companies and academic researchers |
| Research on the development of urban social structure | Pockets of poverty as a new form of social segregation and a germ-cell for the formation of unprivileged suburbs | Scientific and professional articles, expert reports and opinion pieces published in newspapers<br>Weblogs of newspapers and individual policymakers | Participation of researchers in official committees<br>Unofficial communication between researchers and societal stakeholders<br>Presentations and discussion in public policy seminars, participation in weblog discussions |
| Research on reading and writing difficulties | Inability of children under school-age to construct a connection between a letter and a phoneme as a precursor of dyslexia | Diagnostic tests, teaching material and textbooks<br>Graphogame, GraphoWorld<br>LukiMat Internet Platform | Professional further education for teachers and psychologists<br>Test development with schools<br>International GraphoWorld research network |

application and gave birth to collaborative relationships with societal stakeholders. This kind of cyclical development cannot be well interpreted either by using the linear model of achieving social impact or by a fully-fledged interactive model (Balconi et al. 2010). The precursor, i.e. inability of a child to connect letter and phoneme, was a predictor of learning difficulties, explanation of dyslexia and an indicator of an area where the intervention should be directed. An identical situation holds true for other studied research and we believe that additional case examples would provide further evidence in support of strong interdependency between scientific understanding and practical problem solving.

Regarding the artefactual and institutional-interactional dimensions, it is evident that the forms of network interaction between researchers and societal stakeholders and the artefacts through which the societal impact of research was achieved were discipline-specific. Each of the networks was embedded in the institutions of the given social domain, such as plant biotechnology industry, regional planning system

or basic education. Further research on networking in different research areas would enable development of more specific frameworks designed to facilitate related productive interactions in different disciplines, i.e. attempts by stakeholders to apply research results in ways that bring about behavioral changes in society (Spaapen and van Drooge 2011). The development of information and communication technologies offers new ways of interaction to facilitate interaction, as was exemplified by weblogs in urban research and Internet-mediated platforms and online games in learning difficulties. In the future, these kinds of means will become all the more important for science-society interaction and deserve special attention.

The analysis of societal impact of research may be viewed as part of a new contract between science and society. In line with this, researchers should put strong effort in explicating the benefits of their research for politicians, practitioners and other interested users. Such an effort differs from writing publications for disciplinary audiences and is easily neglected due to the pressure to publish peer-reviewed papers. The dialogue between researchers and social stakeholders is essential in a deliberative democracy. In the knowledge society, an increasing number of people have tertiary education, in addition to which strong professional and lay communities have emerged. This creates new possibilities for extended peer dialogue between researchers and practitioners. We believe that our three-dimensional framework of understanding the social impact of research could be used in formative and dialogical peer evaluation of research to foster learning and social improvement (Bornmann 2013; Molas-Gallart 2014). It may be used in articulating societal impact of research in research proposals and in evaluating research programs and disciplines by research funding bodies. The approach is useful for researchers themselves as it stimulates self-reflection in research communities, and may serve as a tool in increasing public understanding of science.

Our framework underlines the significance of the contents of research by focusing on epistemological, artefactual and institutional-interactional dimensions of science. In the future, an additional dimension might be added to the schema: education of scientific literary experts who constitute a key foundation for absorptive capabilities in firms and other organizations (Cohen and Levinthal 1990). This could be included as a "career dimension" in the framework by following the subsequent careers of graduated members of the research groups as they continue their work in other positions in society. This might help us better reveal the cultural competencies and human capacities developed in academia, an issue which was imperfectly illustrated by the three case examples analyzed here.

In the case of learning difficulties, the human capabilities were addressed in terms of the Finnish school system. In a recent study, Finnish citizens were asked about the most important national achievement during the history of their country (Torsti 2013). Against expectations, the most popular answer was the universal educational system, which was appreciated both as a foundation of social equality and an increasingly important factor in economic development. It is well known that 15-year-old students in Finland have scored the highest grades in the PISA tests across Europe, and that differences between schools in Finland are the lowest in OECD countries. All this was achieved without national accountability of results. Educational administration, school teachers and public opinion strongly oppose

public dissemination of school-level information about student achievement as it would easily undermine teaching quality and lead to increasing differences between institutions (Miettinen 2013). This fact alone questions the omnipotence of the unitary accountability systems based on high-stake testing, an internationally-dominant approach in educational policy. In research evaluation, a similar resolution should be opted for by adopting developmental approaches in fostering science-society interaction. For this to happen, new vocabularies and perspectives, such as that developed here, are needed. With the help of these, the tendency to address the social impact of research through unitary systems of indicators might be complemented with more qualitative, supportive approaches.

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