ARTICLE IN PRESS

STOTEN-20756; No of Pages 10

Science of the Total Environment xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community

Romina Rodela [a,b,*], Dušan Alašević [c,1]

[a] Södertörn University, School of Natural Sciences, Technology and Environmental Studies, Alfred Nobels alle 7, 141 89 Huddinge, Sweden
[b] Wageningen University, Laboratory of Geo-Information Science and Remote Sensing, 6700 EW Wageningen The Netherlands
[c] University of Nova Gorica, School of Environmental Sciences, Vipavska 13, 5000 Nova Gorica, Slovenia

HIGHLIGHTS

- We assessed the interdisciplinary profile of a sample of environmental research projects.
- The framework used integrates research collaborations and epistemic synthesis.
- We performed data triangulation.
- Results indicate this sample being interdisciplinary in a narrow sense.
- Results indicate research with problem solving objectives is preferred over research with a degree of abstraction.

ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form 29 July 2016
Accepted 19 August 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Multidisciplinary
Interdisciplinary
Transdisciplinary
Environmental change processes
Science policy interface
Slovene research agency
Slovenia

ABSTRACT

Contemporary approaches to environmental research are calling for a type of scientific inquiry that is able to bring together the natural and social sciences. This with the aim to advance our understanding of environmental issues and produce synthetic and actionable knowledge meant to address these. Yet, interdisciplinarity research of this type is a demanding and challenging pursuit; many have shown that in certain thematic areas and geographic regions practice falls behind discourse. We bring together ideas about interdisciplinary research collaborations (after Patricia L. Rosenfield) and interdisciplinary epistemic synthesis (after Julie T. Klein) that are used to analyse a sample of research projects funded (from 2006 to 2013) by the Slovene Research Agency. We triangulated interview data (with principal investigators) with document analysis and integrated these with other secondary data. Our results suggest for the sample of environmental projects to be interdisciplinary in a narrow sense, this prevalently within natural and life sciences with little input from the humanities and social sciences. Also, the results obtained suggest that environmental research with unambiguous problem solving objectives is preferred over research with a high degree of abstraction, as involved in theoretical and conceptual work.

1. Introduction

Many scholars have documented and commented on research that crosses disciplinary boundaries (e.g. Becher and Trowler, 2001; Boix Mansilla et al., 2006; Klein, 1990; Porter and Rafols, 2009; Simon and Schiemer, 2015). This type of scientific inquiry, commonly referred to as interdisciplinary research, is understood as a process that brings together insight from two, or more, scientific disciplines with intent and scope. For what regards the field of interest here, environmental studies, interdisciplinary research is understood as relevant and the combination of expertise, and intellectual tools, from several disciplines better suited to deal with the complexity and the uncertainty of environmental problems (Brandt et al., 2013; Hirsch Hadorn et al. 2006; Spangenberg, 2011). But, boundaries between disciplines can be crossed in many different ways and for many different reasons (Klein, 2008; Wagner et al., 2011). A widely used framework to capture this is one that distinguishes between a multidisciplinary, interdisciplinary and transdisciplinary approach to scientific research; each having its own characteristics and implications for science and society (see: Klein, 2008; Rosenfield, 1992). However, this viewpoint on scientific research not only indicates for a change in *how scientific inquiry is conducted*, but also points for a change of the *role scientific inquiry has* in our society today, where for instance, decision makers are increasingly asking for socially relevant research and usable knowledge (for details:

* Corresponding author.
E-mail address: rominarodela@hotmail.com (R. Rodela).
[1] DA has moved from this address.

http://dx.doi.org/10.1016/j.scitotenv.2016.08.144
0048-9697/

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

Dilling and Lemos, 2011; McNie et al., 2016). Contemporary environmental challenges impact on the social, economic, and political sphere and so there is need to bring together the natural and the social sciences in a joint collaborative endeavour to further our understanding of the causes, the effects and the ways in which the society can cope with these (Bornmann, 2013; Castree et al., 2014; Corbera et al., 2015; Funtowicz and Ravetz, 1993; Simon and Schiemer, 2015; Spangenberg, 2011).

In this, one cannot neglect that *interdisciplinarity* and *socially relevant* research are both the product of specific processes that occur within given contexts e.g. countries, academic communities, and as such are influenced by social, political and economic aspects. Yet, not much research has been done about this. If we take as an example the European Union, made of 28 Member States the extent to which these countries differ in terms of *scientific excellence* expressed in publications and citations is well documented (see: Kozak et al., 2015; UNESCO, 2010), but little is known how these perform and differ on *interdisciplinarity* and on *socially relevant research.* It is specifically Central and Eastern Europe to have received scarce attention from the research evaluation and science-policy community (see: Good et al., 2015). Comparative studies about scientific excellence, among which the most recent is performed by Kozak et al. (2015), show that researchers based in West Europe are in great advantage compared to those based in Central and Eastern Europe (CEE) who underperform on a range of indicators (see: Kozak et al., 2015). On the other hand, little has been discussed how contextual factors (e.g. political ideology in the past) influence(d) scientific inquiry, how the above trends take shape in (transition) national contexts and the way academic communities cope with changing demands and expectations towards science in this region. In this analysis, we aim to discuss some of these issues. We focus on one of the Central and Eastern European countries, Slovenia, and use a framework that distinguishes between a multidisciplinary, interdisciplinary and transdisciplinary approach to scientific inquiry (after Klein, 1990; Rosenfield, 1992) to analyse a sample of environmental projects. The specific objectives of this analysis are i) to identify how researchers cross disciplinary boundaries by applying the multi-, inter-, trans- framework (Fig. 1), ii) map disciplines from where researchers chose to borrow and iii) discuss how contextual aspects influence interdisciplinary environmental research in this case.

In the next Section details of the conceptual framework used are given. Then we provide methodological information followed by a discussion of results.

2. Work across and beyond disciplinary boundaries

Interdisciplinary research has gained currency. Researchers are increasingly turning to disciplines different from the one they specialised into to borrow ideas, terms, theory, assumptions, methodologies, data collection and analysis methods then used in their scientific endeavours (Porter and Rafols, 2009; Klein, 1990; Wagner et al., 2011). This trend is, on the one hand, driven by disciplinary limitations and impossibility of one discipline to address contemporary environmental issues comprehensively. On the other hand is driven by expectations for a type of outcomes scientific inquiry should deliver which are often described as innovative and cutting-edge (Klein, 1996; Porter and Rafols, 2009). That is, interdisciplinary research is seen to be innovating on a range of contemporary topics/issues compared to a narrowly specialised disciplinary inquiry where scholars are replicating and/or re-arranging the same set of intellectual tools offering versions of already discussed ideas. Interdisciplinary work is deemed to be able to generate groundbreaking outcomes.

Interdisciplinary scientific research can be performed in different ways and aims for a range of impacts. A useful framework to capture the diversity of purpose and performance is one that distinguishes between a multidisciplinary, an interdisciplinary and a transdisciplinary approach to scientific inquiry. An important contribution on this is

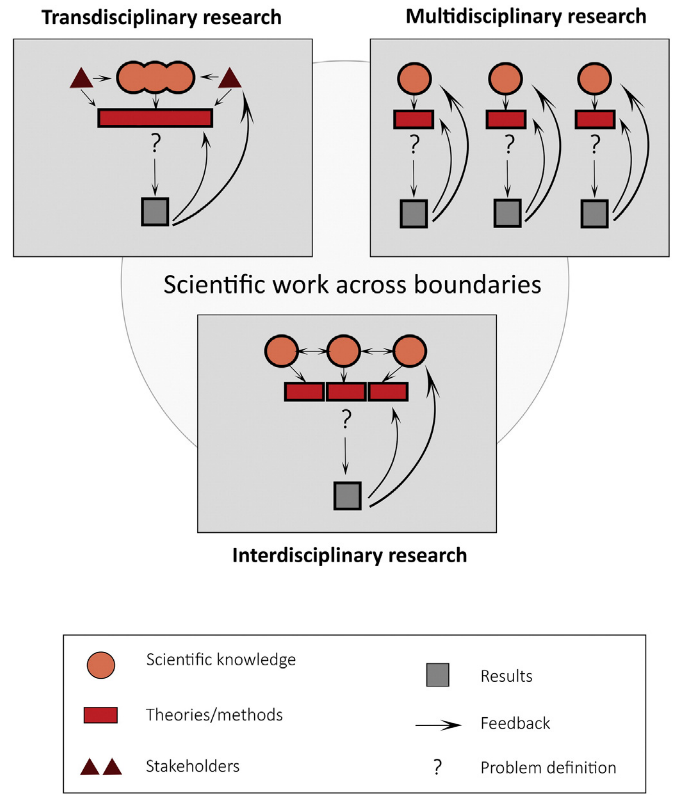

Fig. 1. Research work across scientific boundaries (based on Rosenfield (1992) and Klein (1990, 1996)).

that by Rosenfield (1992) and Klein (1990, 1996, 2010) who have each provided solid descriptions and considerations about the manifestation and implications these have for science *and* society. The two scholars differ greatly when it comes to operationalizing interdisciplinarity; Rosenfield (1992) has looked at *research collaborations*, while Klein (1990, 1996, 2008) prefers to focus on the epistemic dimension involved in boundary crossing and so emphasises *knowledge integration* (see also: Boix Mansilla et al., 2006, Huutoniemi et al., 2010). While looking at quite different underlying processes both *research collaborations* and *knowledge integration* are a legitimate measure of interdisciplinary work and are nowadays widely used by many other academics to study interdisciplinarity. On this Wagner et al. (2011) commented that those adhering to the first, thus looking at *research collaborations,* are prevalently disclosing how people work together and whom they cite (examples of studies: Bjurström and Polk, 2011, Castree et al., 2014; van Rijnsoever and Hessels, 2011), while those adhering to the second are disclosing issues and opportunities associated with the mixing of different knowledge and epistemic synthesis (examples of studies: Huutoniemi et al., 2010; Turner et al., 2015).

For the present analysis we choose to bring together the insights from both scholars to analyse empirical material of our interest. Based on their work, in the following we provide a summative description of what we understood to be major differences between the three approaches to boundary crossing - visually represented by Fig. 1 - and where appropriate consider influences on science-policy and access to research funding (i.e. contextual aspects). This analysis is about crossing disciplinary boundaries for this reason we do not consider monodisciplinarity in the framework used. Also, it is relevant to note that as used here the framework does not seek to convey normative expectations as all three types of interdisciplinarity are seen equally legitimate and useful.

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

Multidisciplinary research is understood as a type of boundary crossing where different disciplines offer *multiple* perspectives on the same issue (Rosenfield, 1992; Klein, 1990), which is done in ways not to challenge the participating disciplines. Klein (1990) highlights how most of the research she surveyed which follows a multidisciplinary approach would be conducted from within different disciplines all focused on one issue. Each of the participating disciplines would select and identify the research questions to be investigated, will select methods for data collection and analysis of own choice and the knowledge produced during the process would feed back into the discipline of belonging where will inform future research practice. She comments how, under such circumstances, the analysis performed within one of the participating disciplines is unlikely to impact the other disciplines involved. Although participating disciplines have evident limitations for the cause at hand, given that help was sought elsewhere, multidisciplinary research would engage little with (how, why, where) these limitations per se. For this reason Klein (1990) sees multidisciplinary research as cumulative; stocking knowledge within delineated disciplinary territories with no intent to engage (critique) others/participating disciplines. Also, multidisciplinary research is unlikely to involve, or aim for, knowledge integration in a cognitive sense (as after Klein, 1990). For these reasons multidisciplinarity is often described as a process where the key aspect is *teaming up of scientists* with (disciplinary) expertise, who are pooled together in order to address a specific issue each from his/hers own (disciplinary) perspective (Klein, 1990, 1996; Rosenfield, 1992). As a result, participating researchers are likely to present research outcomes at disciplinary conferences and publish in disciplinary journals.

This type of collaboration is often found in large consortia with clearly delineated Working Packages that foresee no, or minimal overlapping activities. Rosenfield (1992) noted that while multidisciplinary research needs people to engage in *cooperative behaviour* it does not require that researchers learn and understand the conceptual frameworks and theories of all the participating disciplines. Multidisciplinary research can be done by a lone researcher as well, with the given limitations of the case when a researcher might, for instance, choose to borrow a method, tool or analytical approach, without undertaking a throughout study of the conceptual framework/theory underpinning the item borrowed.

Accordingly, it is not surprising that when it comes to funding multidisciplinary proposals PI might prefer to apply for funds (e.g. applications to Research Councils) within their own scientific field where they are well established and their capacity to innovate is known to colleagues- scientific reputation increases the likelihood for a PI to get a proposal funded (see: Merton, 1968 on cumulative advantage/Matthew effect in science). On this it is useful to note that the way scientific disciplines are grouped together (as part to a *classification system* used by Research Councils) will influence access to funds allocated as part of total R&D. It is common that fields more likely to contribute at national policy objectives will get a higher share and for this reason the humanities and social sciences often fall behind natural and life sciences. Within the European Union, to which Slovenia is a member since 2004, the OECD Frascati[a] classification of science and technology is used, it consists of six scientific fields: i) Natural ii) Engineering and Technology Sciences iii) Medical and Health Sciences iv) Agricultural Sciences v) Social Sciences vi) Humanities.

Interdisciplinary research is described as a tighter *collaborative process* (Rosenfield, 1992; Klein, 2008). Klein (1990, 1996, 2008) writes that in interdisciplinary research the participating researchers engage with one another early on in the process, and for instance jointly identify research questions, select methods for data collection and analysis. Scientists, while operating from within own epistemic tradition, become engaged in the development of a shared understanding of the phenomenon under investigation. They might get involved in an exchange of knowledge during the different steps of the process and this can foster cross-fertilisation of ideas and mutual influence. The resulting insight may find a place in co-authored papers published in interdisciplinary journals, books, etc.

Interdisciplinary research requires a different cognitive effort as compared to the earlier approach. Rosenfield (1992) writes that it requires learning and understanding of conceptual frameworks and theories of the participating disciplines as she foresees that interdisciplinary projects involve collaborative activities where several disciplines participate actively on shared tasks during the research process and see a common goal. An example she provides is the collaboration between a sociologist and an epidemiologist working on a survey seeking to investigate socio-economic influence on disease manifestation - each needs to familiarise at least with the basic notions of the other participating discipline. Also, Klein (2008) sees interdisciplinary research as a process requiring a type of cognitive involvement. She often describes it as a generative process resulting from the mixing and blending of disciplinary knowledge that shall ideally lead to epistemic synthesis. This involves, however, a different handling and processing of knowledge compared to multidisciplinary research where for Klein (2004) knowledge is simply juxtaposed (i.e. placed side by side for comparison or contrast) but not integrated (i.e. blended for an improved understanding).

Interdisciplinary research is ground where critique takes form; the limitations of disciplinary viewpoints are not hidden or ignored and often are openly discussed which may lead to new opportunities and understanding (Klein, 1990, 1996). In her survey of scientific literature Klein (1990, 1996, 2004) finds that interdisciplinary research where a critique of disciplinary viewpoints is openly formulated rarely succeeds at shaking the legacy of well-established disciplinary tenets. In cases where fundamental issues, or limitations, are unveiled the formation of new research fields, where dissidents can find a new intellectual home, is more likely to occur (Klein, 1990, 1996, 2004). Reform of disciplinary assumptions appears to be rare and harder to pursue. Ecological Economics is a case in point. The critique formulated by some (ecologically literate) economists to mainstream economics, during the 1980s, gained traction in the 1990 leading to the establishment of international associations, scientific journals, BSc MSc and PhD programs, and is today a well-recognised research field - Ecological Economics (Kastenhofer et al., 2011). However, despite the academic recognition that critique did not succeed at changing mainstream economics (Røpke, 2005).

Insight into how research fields emerge, develop and dry out comes useful for science policy, specifically in weighting the use of classification systems (e.g. OECD Frascati, CERIF[b]) to distribute funds. It has been already discussed that interdisciplinary research suffers from classifications given that it does not fall neatly into one disciplinary domain and so it runs the risk to be ignored or under-valued. The OECD Frascati system, used in the EU, does not give very much space for interdisciplinary research, but countries use a range of strategies to make space for it. For instance in the Netherlands the Dutch Research Council (i.e., NWO) foresees the possibility for proposals to be submitted at an interdivisional panel, while in Slovenia an additional category "Interdisciplinary studies" has been added in the 1990s to the now still used classification system of scientific fields (Frascati adjusted). Occasionally ad-hoc measures, to address perceived needs/gaps in terms of emerging trends in boundary crossing, are also used. For instance *environmental social sciences and humanities* (ESSH) is a fast growing (interdisciplinary) research field gaining recognition internationally (see: Castree et al., 2014; Palsson et al., 2013). The Swedish policy-makers identified a

[a] The OECD Frascati classification of science and technology is a general taxonomy where the main scientific fields appears as a first-level category (e.g. Social Sciences) while disciplines as a second-level (e.g. Economics).

[b] CERIF - Common European Research Classification Scheme.

[c] Full evaluation report available at: http://www.formas.se/PageFiles/5409/Mobilising%20Swedish%20Social%20Science%20Research.pdf

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

strong need for it in the country[c] and soon after the Swedish Research Council launched a major ad-hoc call for projects in this interdisciplinary field meant to address the identified need.[d]

Transdisciplinary research is the one of most recent appearance and most closely linked to expectations for science to be useful and socially relevant. Transdisciplinary research is often discussed as a process where stakeholders participate to the research process either by selecting/identifying/prioritizing issues, providing or checking data, validating or using the outcomes (Rosenfield, 1992; Klein, 2004). Rosenfield (1992) writes about transdisciplinary research as a process involving policy makers and communities whom should get some help from the research being done and describes these “non-academic groups” to be on the “receiving side”; benefiting from the scientific outcomes. This viewpoint comes along with the suggestion for the scientist to be active in dissemination beyond academia targeting potential users e.g. write and speak for popular media. Rosenfield (1992) herself did not comment on how and whom dissemination shall target, others did. For instance many Research Councils ask for far-reaching dissemination plans able to address diverse audiences of “potential” interest. This often means that scientists should learn how to talk about research in an accessible and engaging way, and show the societal relevance of the work done (and money spent) widely.

Klein (2004) discusses trasdisciplinary research in a different way. With attention for the epistemic dimension involved in boundary crossing, having established that multiple stakeholders are involved and contributing heterogeneous skills and expertise, she allows for the possibility that within the transdisciplinary approach research problems are not formulated in strict scientific terminology. Differently from multi- and inter- disciplinary approaches, trasdisciplinary approach questions disciplinary thinking and seeks to go beyond reductionism, segmentation of ideas and problem solving (Klein, 2004, 2008); when place for others is allowed this means they will bring along different understanding and values. Klein (2004) notes that trasdisciplinary research should allow for instrumental, ethical and aesthetic forms of knowledge to sit side-by side to scientific knowledge. There are many examples of research where for instance traditional knowledge has been integrated in the research process (see: Armitage et al., 2011). But this type of collaborative arrangement is challenging; it requires a new *modus operandi* where non-academic groups/stakeholders get involved in knowledge production and so, it is assumed, are also given a degree of influence over it e.g. partaking in monitoring and evaluation as part to an *extended peer review* (Funtowicz and Ravetz, 1993). On the other hand, scientists need to learn how to work fruitfully with non-academics, how to negotiate and agree on outcomes that are meaningful to all the participating profiles.

Again it is revealing to look at how science-policy filters ideas and how funding agencies act upon these. For instance the Targeted Call[e] launched by the Swedish Research Council in 2016 read “*Co-financing and collaboration with building and planning stakeholders is a prerequisite for funding support. Co-financing and collaboration must be described and justified in the application. Collaboration may for example take the form of joint development of research questions, which are then investigated in the project by the active participation of different actors*.” Also in Slovenia comparable grants, i.e. the 2015 call for Targeted research projects[f] focuses on pressing societal needs/issues, but do not require for early stakeholder involvement given that research topics/questions (with a good level of detail) are in a first place identified, selected and announced by Ministries and/or state agencies and researchers apply to implement the work.

To conclude, for the aforementioned reasons, we like to note here that for what regards interdisciplinary environmental research it is relevant to establish whether an exchange between the natural and the social sciences has occurred and which disciplines were involved (see also: Heberlein, 1988; Castree et al., 2014). Both Rosenfield (1992) and Klein (2004) recognize that differences in how researchers are able to access, process and understanding insight from scientific fields, different from the ones they belong to, influences choices and borrowing practices. Becher and Trowler (2001) as well as Klein (1996) note how researchers are more likely to engage with, and borrow from, disciplines that have a degree of epistemological proximity. For instance the conceptual distance, or proximity, between mathematics and statistics is likely to favour collaboration across these two compared to mathematics and history which are epistemological more distant. Therefore, when investigating interdisciplinarity it might be revealing to look at the participating disciplines and consider the conceptual distance involved.

3. Methodology

The objectives of the research reported here was to analyse how Slovene scholars who are busy studying environmental issues go about crossing disciplinary boundaries and to reflect how contextual aspects influence interdisciplinary environmental research. Given the task at hand we choose to undertake interviews with PI (principal investigators) and integrate these with secondary data available on-line from SRA (resources allocated, classifications) and SICRIS (written reports, information about outputs, performance, and partnerships). The Slovene Research Agency (SRA), established in 2003, is the institution managing, selecting and allocating public funds for scientific research and in several cases this is done in collaboration with sectorial Ministries. Prior to 2003 this was entirely within Ministries, but as stated by F. Demšar (former SRA Director) during an open lecture commenting on the SRA, in the view of European integration “*Slovenia needed a (politically) independent body who could allocate funds in a transparent way and promote scientific excellence*”.

For the present study we choose to focus on scientific research projects (co)funded by SRA. These projects take the form of i) basic, ii) applied, iii) targeted and iv) post-doctoral research projects (the post-doc is the PI and has great independence), have a lifetime from 2 up to 4 years and all the scientific output produced is registered in the Slovenian Research Information System - SICRIS.[g] Funds for these projects are granted on the basis of annual calls. The SRA coordinates a further scheme the *research programs* meant to support research teams over longer periods i.e. 5 years, however, for methodological consistency we choose not to include these here.

A key question for any study of this type is how scientific research is classified e.g. soft vs. hard, natural vs. social sciences (see: Becher and Trowler, 2001). The OECD Frascati recommendations are those most used across Europe, but the SRA choose to harmonise only in part and has kept some earlier classifications. The SRA groups science into six fields where disciplines and sub-disciplines are identified and in Annex 1 we give our translation of the scientific fields given that the wording of some of the SRA translations are not the ones most used in English. For instance the discipline of our interest classified as *1.08 Varstvo okolja* appears in this form in SRA and SICRIS, but when it comes to translating this term it in English, SRA translates it into *1.08 Control and care of the environment* while in SICRIS it is translated as

[c] Full evaluation report available at: http://www.formas.se/PageFiles/5409/Mobilising%20Swedish%20Social%20Science%20Research.pdf

[d] Call and results available at: http://a4.mndcdn.com/image/upload/xn1aoangypfdjoggen2x.pdf

[e] http://www.formas.se/en/financing/calls-for-proposals/211-million-sek-to-a-strategic-call-within-the-area-sustainable-building-and-planning.

[f] https://www.arrs.gov.si/sl/progproj/crp/razpisi/15/razp-crp-15.asp

[g] SICRIS is a database with information about research performance expressed in points *per* type of output delivered by individual researchers (first level of assessment) which can be clustered and checked also for higher levels as is projects, programs, departments and organizations. The information feeds in through a link at a bibliographic database i.e. COBISS where information is inserted by librarians upon author's request. SICRIS has been funded and is used by the Slovene Research Council to allocate funds: when a call is out and a PI submits a proposal the evaluators will look at the total score expressed in numbers the PI and the team has got.

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

1.08 Ecology. The way disciplines are named matters so for the present analysis we choose to translate it to better reflect the meaning as it appears in Slovene language: i.e. *1.08 Environmental protection*.

We started the analysis with a bibliographic search into SICRIS (http://www.sicris.si) where data about research benefiting from public funds is stored and first searched within *1.08 Varstvo okolja* (*Environmental protection*). Results were screened against three inclusion criteria: i) projects were granted funds in the period from 2006 to 2011, ii) were completed by 2013 and iii) were about environmental protection. Projects which did not met these criteria were excluded. For instance a project (id. V4-0487) that run from 2008 to 2010 was excluded since it did not pursue environmental protection (criteria no.3), but sought to contribute at improving agricultural production in the country. Aware that some research of interest might not be registered under 1.08 we searched also within other classifications and multiple cross-checks led us to shortlist 40 projects.

In a second step we approached the PI of all the 40 projects by e-mail with an interview request and 25 PI agreed. Some of PI have managed two projects from our sample and were interviewed about both - we talked about 28 projects in total (project no. 11a and 11b are summarised in one Report so have counted them once as PI reported to SRA). We pilot tested the Slovene version of the interview guide (an English translation available as an Annex) used during semi-structured interviews, these were conducted between October and December 2013 and lasted from 20 to 45 min. 13 were done face-to-face and upon permission tape recorded, while 12 interviews were done by telephone and notes were taken. Interviews were transcribed, upon an expression of interest a copy of the transcript emailed. Copies of the audio and text files were safely archived. All interviews were conducted, transcribed and archived by the second author.

Quantitative data about individual projects, available in SICRIS, was extracted and inserted it into a database where we inserted also information obtained from interviews after coding it (Table 1). Both authors coded the data collected with disagreements (over three projects) being resolved by double checks of project reports. Further to this, interviews we used to cross-check information (extracted from SICRIS) and to get a deeper insight into researchers' experience and opinions about boundary crossing. We analysed interview data by searching for trends then used for the analysis.

It is useful to mention that both authors, albeit in different roles, were members of the Slovene academic community and have made extensive use of COBBIS and SICRIS for their research.

Table 1
Codebook.

Analytical items	Codes
SRA project typology	1 Targeted research projects
	2 Post-doctoral projects
	3 Basic research projects
	4 Applied research project
Environmental issue	1 Water pollution
	2 Renewable energy
	3 Toxic pollution
	4 Radioactive pollution
	5 Nature protection
	6 Marine protection
	7 Risk assessment
	8 Soil pollution
	9 Waste pollution
	10 Chemical pollution
	11 Air pollution
	12 Forest protection
Conceptual distance [1]	1 Narrow
	2 Medium
	3 Broad
Problem definition jointly with stakeholders	1 Yes
	2 No
Borrowed data from other disciplines	1 Yes
	2 No
Years of research experience	1 Under 20 years
	2 Over 20 years
Lead researcher	1 Male
	2 Female

Note: [1] To determine conceptual distance we used the SRA classification (translated as an Appendix), which is the officially accepted and used in this country.

4. Results and discussion

This analysis uses a combination of quantitative and qualitative data, in the following we present and discuss the results obtained against aspects of interest.

4.1. Sample description

The SRA classifies research projects into four types and our sample includes 11 targeted research projects, 9 post-doctoral research projects, 5 basic and 3 applied research projects (Table 2). These cover eleven different environmental issues; 9 (32%) are about water pollution 6 (22%) are about soil pollution, 4 (14%) are about forests protection, 3 (11%) are about toxic pollution, other 6 (25%) projects are about renewable energy, nature protection, marine protection, risk assessment, waste pollution, chemical pollution and air pollution (Fig. 2). A total of 19 projects (67%) were led by female PI and 9 (33%) by male PI who, according to SICRIS data, have jointly coordinated 231 people (senior and junior researchers and technical staff).[h] With the exception of a few cases most of the PI described well-functioning project teams (i.e. researchers based at different departments/institutes) and mentioned further joint projects as a proof of cohesiveness. All of the PI expressed satisfaction with project implementation, all research projects delivered the expected outcomes and reports were submitted in time and from the answers received it appears all PI have good managerial skills. In acknowledging the quality of the research outcomes produced (e.g. publications, data-sets, analytical methods, patents) most saw value and importance of these for academia and stakeholders within the country. A few pointed at international importance, but none of the respondents has identified the work performed as of a major ground-breaking scientific relevance.

A closer look at Table 2 shows a substantial difference in how resources were distributed across environmental issues which may point at some trends and for further insight we looked at project reports. In this pollution control, pollution mitigation and remediation of contaminated sites were most frequently mentioned research objectives in the reports accessed. In the past Slovenia, as other countries in CEE, focused heavily on industry seen by the political elite of that time as the main economic drive able to absorb large amounts of labour, generate economic stability and so help to keep things under control. But that choice has left a heavy burden on the natural environment still felt to the present day mostly by those living within or near industrial districts (Plut et al., 2001). The data collected indicates that a large amount of current research effort funded under 1.08 *Varstvo okolja* (*Environmental protection*) is directed at the study of pollution/pollutants and/or mitigation of environmental pressures linked to policy decisions made in the past (Table 3). Only 7 ($N = 28$) projects from our sample are about other topics than mitigation and remediation of environmental burdens (Table 3). On the other hand, topics which are getting international scientific and policy attention as is adaptation and mitigation to climate change, ecosystem services, and similar are largely absent from our sample. Big absentees are also novel governance approaches (e.g. co-management) to the study of environmental issues - those which took ground internationally in the 1990 and have exposed the

[h] We came across a few projects that employed less team members as reported in SICRIS. According to one respondent SICRIS lists people appearing in the proposal, but not factually working on the project. From SRA we learned that keeping information up to date is the project manager responsibility. A detailed check on personnel was not our objective and we did not verify engagement in all cases.

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

Table 2
Distribution of resources across project (SRA) typologies.

Type of the project	Number of people involved	Number of institutions/organisations involved*	Budget €**	Percent of total budget (%)	Number of projects
Targeted research projects	131	33	804.530	28	11
Postdoctoral projects	9	9	815.298	28,4	9
Basic research projects	55	13	763.445	26,6	5
Applied research project	36	5	491.041	17,1	3
Total	231	60	**2.874.313**	100	28

* As reported in SICRIS. ** SRA reports project budgets for years prior to 2008 in Slovene currency (SIT) and those after 2009 in Euros. We converted all into Euro by applying the current conversion rate.

limitations of top-down environmental decision making, the limitations of unconstrained use of prediction models and so formulated a critique to the command-and-control approach.

4.2. Boundary crossing

One of the objectives of this analysis was to discern how researchers within this academic community cross disciplinary boundaries by applying the multi-, inter-, trans-framework (Fig. 1). Therefore, taken into account scope and outcomes we come to classify **11 projects as multidisciplinary** (Table 4). Across these we observed a recurring pattern in how work was organized; different disciplines were juxtaposed to address a given objective with no intent to challenge disciplinary viewpoints, or search for overarching integration. Differently from Klein (1990) who in her study saw that within one project more disciplines approached an issue (with a full research cycle) our respondents talked about crossing disciplinary boundaries in relation to one-phase of the research cycle only. Often that was during data collection, analysis and/or interpretation. One such case is project no. 15, a post-doctoral research, looking at the effects of air pollution on lichen (i.e. biomonitoring) where the PI identified biology as the main organising and contributing discipline, mentioning chemistry as the second discipline from where to borrow analytical tools, but without aiming to feedback into chemistry. The respondent reported about learning chemistry "stuff", but also mentioned interest to contribute at own research field of belonging mostly. Similarly the PI of project no.23, also a post-doctoral research, who focused on hydrogeochemistry of karstic aquifers reported of having chosen to combine in novel ways methods from physical and analytical chemistry (i.e., hydrogeological data and geochemical parameters of rock and water) that were however performed by other researchers/experts (one laboratory Slovenia one in Canada). Then, the results were used by that PI for an overarching geochemical analysis of water taken from 90 wells from carbonate aquifers across Slovenia for which he used analytical methods from statistics. The insights that emerged were published in journals specialising in geology and/or sister specialties hydrogeochemistry (i.e. Materials and Geoenvironment, Aquatic geochemistry) which are this PI's discipline of belonging.

Then, we classified **7 projects as interdisciplinary** since the PI talked on linking insight from different disciplinary domains and reported on how this allowed them to develop new methodologies, helped to identify inconsistencies of earlier work or prove it wrong (Table 4). This, we assumed, suggests for the presence of a critical outlook. For instance the PI of project no. 18 talked about integration of methods, from analytical chemistry and biology, and of comparing the two set of results obtained to study the influence chemical substances have on viruses. The results were presented at a national gathering of microbiologists while the novelty of that work led them to register one patent. Also the PI of project no.13 talked about integration of methods that are pioneering work for Slovenia (but mentioned these being well established internationally). Project no.13 sought:

"*to better understand bio-geochemical cycles of chemicals present in the environment as contaminants and to predict their impact on biota and humans*" and so it brought together chemistry and environmental sciences. The empirical part was performed within analytical chemistry - it looked at the potential of isotope dilution technique for the quantification of trace elements or their chemical forms in various environmental and biological samples. The PI told us that they succeeded to prove that currently used methodologies are biased - since are underestimating certain aspects and not able to establish with precision the concentration of hexavalent chromium (a carcinogen substance) – which she contextualized within environmental management and law specifically. Thus, if the respondents from the earlier multi-group talked mostly about juxtaposition of insight for a given purpose, this group of

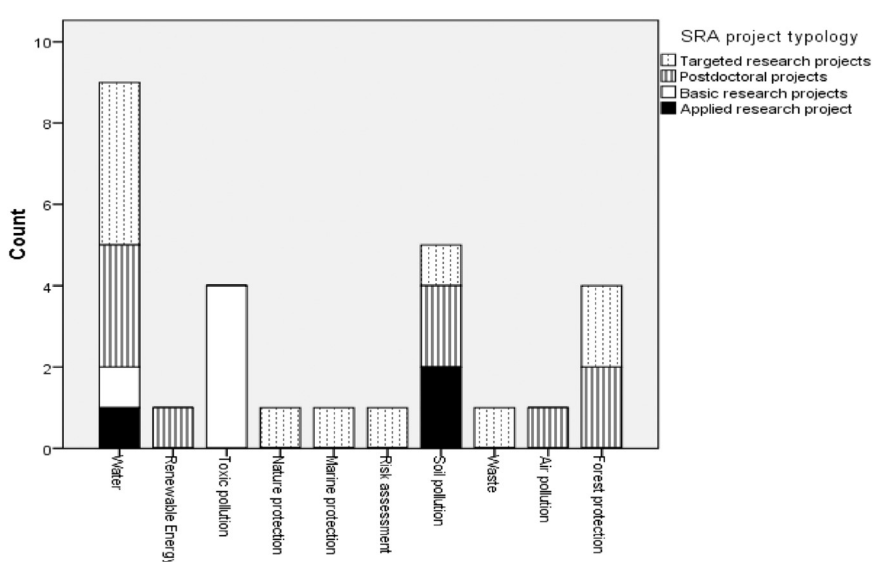

Fig. 2. Research focus across project typology.

Table 3
Distribution of resources across thematic areas.

Environmental issue	People involved*	Budget €**	Percent of total budget (%)	No. of projects
Water pollution	76	819.593	28,5	9
Soil pollution	45	603.455	21	5
Toxic pollution	40	600.039	20,9	4
Waste mngt	25	89.900	3,1	1
Forest protection	19	314.568	10,9	4
Risk assessment	13	160.000	5,6	1
Marine protection	6	75.000	2,6	1
Nature protection	5	58.000	2	1
Air pollution	1	52.739	1,8	1
Renewable energy	1	101.019	3,5	1
Total	231	2.874.313	100	28

* As reported in SICRIS. ** As reported in the SRA on-line archive.

respondents talked about mixing disciplinary insight in a way that allowed them to challenge, or that allowed them to open, or import from outside into the country, research lines and topics. Both Rosenfield (1992) and Klein (1990, 2004, 2008) see interdisciplinary research as a type of work involving a higher degree of cognitive involvement compared to multidisciplinary research. This aspect, however, did not come forward strongly in the interviews we made which could be on the one had linked to the (coordination and management) role our respondents had, but on the other hand we blame the interview guide used (Appendix II). In the attempt to cover the many and different aspect of interest it gave us limited opportunities to explore in detail respondents´ cognitive involvement in the research performed. In hindsight we see cognitive involvement a topic needing an interview guide on its own.

The analytical model detailing types of interdisciplinarity used (Section 2) foresees that **transdisciplinary research** involves non-academic groups. Rosenfield (1992) talks about transdisciplinarity as research where communities and policy-makers are those benefiting from the outcomes produced by researchers. According to this viewpoint all of the targeted projects would classify as transdisciplinary since research objectives of targeted projects are identified by policy makers/stakeholders who are also those to use the outcomes produced. On the other hand, Klein (2004) argues that transdisciplinary research is better seen as a collaborative process that transcends disciplinary boundaries, and thus epistemic traditions, with non-academic groups having an active role. This viewpoint goes beyond ticking the box if non-academics participated, or not. Rather, it assumes involvement in knowledge production with expertise, viewpoints and ideas. We took on board ideas Klein (2004) formulated about knowledge co-production and therefore come to classify **10 projects as transdisciplinary** (Table 4). On the basis of the answers provided about the level of interaction between researchers and stakeholders before, during and after the research process we classified 8 targeted projects and 2 post-doctoral as trasdisciplinary. It is a known fact (foreseen by current science-policy) that stakeholders i.e. ministries or state agencies, select issues for which a call for targeted research will be opened. On the other hand no research has been done and it is not known how these actors then influence the research process and in which way research outcomes are used by policy and practice. From interview data it comes forward that *efficiency* is a major concern for participating stakeholders i.e. decision-makers. They have, for instance, asked PI of two different proposals (based at different institutions) submitted to the same call to merge them into one to cover more activities with given resources. *Usability* of the outputs produced *vis-a-vis* current policy issues also emerged from interviews. Respondents linked project outputs with obligations that arise for Slovenia from EU membership and to needs for data and products Slovene public bodies have to accomplish with obligations in providing public services/goods. We talked to PI only and for this reason do not have information into ways in which research outcomes produced by targeted research were/are used *in practice* by stakeholders and decision-makers. This is a topic which did not received attention so far in the country, but it would merit exploration. This also because several PI of targeted research projects replied that the work done was *not* about making a scientific contribution but it was about tackling issues and remediating to environmental problems. This has triggered our attention and a second look at project reports confirmed that in some cases indeed there is no reference to scientific outputs e.g., scientific papers, books.

Table 4
Types of interdisciplinarity across project (SRA) typologies.

	Targeted research projects	Postdoctoral projects	Basic research projects	Applied research project	Total	Percent of total (%)
Multidisciplinary	2	5	2	2	11	39
Interdisciplinary	1	2	3	1	7	25
Transdisciplinary	8	2	0	0	10	36
Total	11	9	5	3	28	100

Targeted projects are implemented as part of a targeted research program whose main objective is to support current policy making and so contribute at societal needs in Slovenia. Targeted projects are co-financed by Ministries, or other public bodies, and since 2001 have always seen strong stakeholder involvement – all features associated with transdisciplinary research (see: Brandt et al., 2013; Funtowicz and Ravetz, 1993; Klein, 1990; Rosenfield, 1992). PI of these highlighted the importance of the work done for the Slovene society pointing how that effort resulted in needed data and products e.g., better manage forest, drinkable water. The fact that the selected targeted projects make more than one third (39,3%) of this sample may point to the presence of a viewpoint about what environmental scientific research should do and in which way.

4.3. Participating disciplines

Several scholars have discussed how researchers are more likely to borrow from neighbouring disciplines particularly from those with ontological and epistemological assumptions close to the one where they see as an "intellectual home" (see: Porter and Rafols, 2009). The motives are many and range from institutional, cognitive, relational, reputational, etc. Data from SICRIS tells that 21 projects form our sample were registered under 1. Natural Sciences (19 Environmental Protection and 2 as Geology), 4 under 4. Biotechnical Sciences (Forestry), 1 under 2. Technical Sciences (Hydrology) and that from SICRIS tells that from the 231 people linked to this sample of projects only 6% ($n = 14$) indicated a specialisation within social sciences (11 geographers, 2 urban studies, 1 interdisciplinary studies).

Specifically, from interview data we gather that while all PI reported on cross-disciplinary engagement 64% projects appear not to have crossed further than the adjacent fields and for instance saw an ecotoxicologist borrowing from microbiology (narrow conceptual distance), while only 32% reached further out into fields conceptually somehow more distant but still sharing a good deal of bits and pieces (Table 5). For instance a hydrologist borrowing from radiophysics (medium

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

Table 5
Types of approaches and conceptual distance.

	Multidisciplinary	Interdisciplinary	Transdisciplinary	Total	Percent of total (%)
Broad conceptual distance	0	0	1	1	3,6
Medium conceptual distance	4	1	4	9	32,1
Narrow conceptual distance	7	6	5	18	64,3
Total	11	7	10	28	100

conceptual distance). The data collected tells that only one targeted project reached much further out into social sciences and has combined insight from agronomy and biology with geography and sociology. Unfortunately, according to the project report that project has not produced scientific outputs so it is not possible to see into the details of that epistemological and ontological engagement. Humanities and social sciences are big absentees in this sample. Since within this sample boundary crossing occurred across specialties within the natural and the life sciences to borrow methods for data collection and analysis mostly.

4.4. Socially relevant research

The impact industry left on the natural environmental is a complex matter with implications for more than one environmental sphere as well as human health. Thus, it does not come as a surprise that *all* PI who managed projects aiming to mitigate, or study pollution/pollutants reported about crossing disciplinary boundaries and this mostly to borrow analytical methods, data or methodologies, which would allow them to do a more comprehensive, novel and in-depth study of the issue at hand. This suggests respondents being well aware of disciplinary limitations and being interested to innovate accordingly. For instance as part to project no. 4:

> "[complementary] *chemical, biological and physical measurements*" were "*performed in a mercury contaminated area …/.. in order to provide the basis for meaningful and cost-effective monitoring strategies*" (Report no. L1-0367).[i]

While as part to project no. 9 analytical chemistry, ecotoxicology and eco-technology were brought together to study residues of psychoactive substances in fresh water. A few other projects scaled this up segmenting activities along individual environmental items bringing together different sets of data to make integrated assessments. For instance project no. 17 collected (already available) data about water, air, soil and vegetation for delivering an assessment of the natural environment in a heavily polluted area the Celje Basin. On the other hand, borrowing of ideas or theories only were not that frequently mentioned by the PI nor by the reports which can be understood against the objectives this sample of projects sought to achieve. All projects were focused on concrete issues present in the field and research effort went into activities aimed to mitigate and/or search for solutions to these. So the impression is that selected projects neither included, nor contributed to other more theoretical aspects, let alone ideological issues, that elsewhere are part to the interdisciplinary environmental research agenda.

The dominance of applicative/empirical research, we assume, might have taken away resources, opportunity and interest for engagement on more abstract aspects related to the exploration of theory, concepts and ideas. This could be extended to all projects in our sample since all appear to be issue-based with most PI, even PI of basic research, talking about "*solving problems*" and referring in one way or another to societal needs (Fig. 2). Herewith we cannot ignore the fact that environmental studies historically have a strong empirical base and also international literature most often reports on empirical research; on this aspect our sample is aligned with research practice found elsewhere.

[i] Our translation of Slovene text.

To conclude, data collected eloquently point to a viewpoint that sees the sciences in producing *socially relevant research*. That however without being too much disruptive by asking a very different set of questions, questioning current approaches, using different analytical tools, or involving unusual partners in the research process.

4.5. Contextual aspects

Herewith, we acknowledge that there are limitations to small samples, but it is our impression that this sample signals for general trends in the country, and perhaps widely in the region. Yet, we need to put results obtained into context. Thus, if we look at the research performed beyond these 28 projects it appears to us that in Slovenia environmental issues are approached in different ways by different disciplines and it is not clear if these meet (conceptually) very often. In the country there are several internationally well established and much productive research groups investigating the natural environment, but a closer look at their scientific agenda reveals these operating prevalently either with the "soft" or the "hard" sciences, and publishing accordingly. Scientific papers are only one among other types of scientific output, but the low number of papers reporting on SRA funded research from major international scientific journals specialising in interdisciplinary environmental studies might further support our observations.

Despite our sample bringing together only applicative/empirical research it is important to acknowledge the presence and importance of conceptual writings by Slovene academics. It thus seems to us that those who have touched upon environmental issues in a critical way - prevalently when writing about sustainability - are geographers who are classified by SRA as Humanities. The absence of full departments specialising in environmental policy, environmental psychology, environmental sociology, environmental governance, and similar, across four Slovene Universities which could add perspective and build *momentum*, resulted in geography being the main "soft" discipline looking at environmental issues in a "different" way (e.g. questioning, exploring, critiquing). This is not to say that there is a complete vacuum. There are indeed several individuals, who are not geographers that write and run projects on a range of environmental topics. This, however, is most commonly done at departments specialising in well-established disciplines either within the social or the natural sciences with its own (research) agenda. Environmental issues are a complex subject that require an articulated and in-depth analysis – a geographer viewpoint while valuable and needed remains within the opportunities offered by the analytical and conceptual tools geography can offer. There are limitations to the type of critique one can make with just one set of analytical tools. This is not a minor issue given that depth and relevance of a critique not only influences publishing and dissemination opportunities, but consequently access to research grants that are needed to establish new research lines and sustain a research team over time. Given the role and space geography has in Slovene academia – scholars have published mostly in Slovene language in national peer-reviewed scientific journals on local environmental features/issues. On the other hand, our sample suggests that the "hard" sciences, in taking prevalently a technical /engineering (long proved insufficient by international literature) and problem-solving approach are contributing mostly at remediation of past environmental burdens, or those caused more recently. However, when research is mostly about remediation, and/or is searching for solutions, it is likely that it will, in many ways, contribute at managing

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144

the status quo rather than be exploring alternatives and different ways of doing things (Lotz-Sisitka et al., 2016).

Therefore, in acknowledging dedicated initiatives to bring together the "soft" and the "hard" sciences, e.g. graduate study program Nature Protection at Ljubljana University, we also look at the above described trends and assume for the presence of a viewpoint across Slovene academia and policy, about what constitutes environmental studies in terms of topics covered, approaches and methods used, and what are legitimate disciplinary contributions of these on important social (and policy) issues.

4.6. Implications for future research

What constitutes a good measure of interdisciplinarity and how to perform interdisciplinarity assessments are debated issues (Huutoniemi et al., 2010; Sugimoto, 2010). This analysis taught us two lessons; a first one, relates to the use of publicly available databases for interdisciplinary assessments, a second one relates to the selection of measures for use in assessments.

There is extensive use of bibliographic databases and in most studies the accuracy of information provided is not a topic, or is marginal. Accuracy of databases might not be an issue for studies looking at macro scale processes, but with a sample of 28 projects this was a concern for us. Specifically, we planned to study participating disciplines by mapping team members' disciplinary specialisations, but then we found out that in some cases there is a mismatch with the information provided in the database with factual engagement (for details: Rodela, 2016). We had to change plans and chose to use information about the research fields given for each projects which proved accurate, but in the process have identified some. Thus, during the data collection process we have identifed some "grey areas". Specifically, management and maintenance of massive databases is a challenging task and accuracy of data found in SICRIS, we learned, is a shared responsibility of which however not every PI/researcher is aware of, and so can act accordingly (for details: Rodela, 2016). This aspect has methodological implications for future research planning to use SICRIS, or similar databases.

Further to this, in handling information about consortia as well as personal grants we also learned that the selection of measures used for interdisciplinary assessments should take into account that research takes many forms and shapes. The project no.15 and no.23 (see: section 4.1) are telling cases. Both projects employed one person, the PI/postdoc, who has, as recorded in the SICRIS/SRA system, a clearly defined disciplinary belonging. However, if we would have taken this information only (as from CV, or the SRA code) we would have wrongly coded these as mono-disciplinary. It was only through interviews and project reports (qualitative data) that we were able to establish that disciplinary boundaries were crossed. This observation has broader significance; it suggest that studies of interdisciplinarity can benefit greatly from very different data and the combination of data collection methods used here can help future appraisals in their own choices.

5. Conclusions

Interdisciplinary research into environmental issues has gained prominence. Many, researchers and policymakers alike, are now advocating for knowledge accumulated about the natural and the social system to be brought together and used to address environmental issues our society is facing. We were interested if the Slovene academic research community crosses disciplinary boundaries, which disciplines are pooled together and how that serves environmental protection. The results that emerge allowed us to identify an academic community which is very active in crossing disciplinary boundaries, but this mostly into neighbouring disciplines, prevalently with natural and the life sciences, to borrow methods for data collection and analysis, but seems not so much engaged with humanities and social sciences. Also, we observed that environmental research with unambiguous problem solving objectives is preferred across academia and policy over research with a high degree of abstraction e.g. theoretical and conceptual work.

Search for solutions (i.e. problem-solving orientation) is important, but on the other hand it should not hijack academic attention from critical engagement, from exploration of different questions, topics and alternative approaches. Also for this reason we see the need for interdisciplinary scientific inquiry to be looking further out and bring together the natural sciences with the humanities and social sciences. The framework used proved useful on further grounds. It helped us to deconstruct engagement with stakeholders and identify that in a few cases scientific excellence has fallen behind "useful" and socially relevant objectives. This last is particularly interesting also because it goes against current assumptions about what transdisciplinary research can and should deliver, and in which way. Understanding these processes is not a minor issue thought; it proves useful when it comes to adjustments of *science policy* and can support the introduction of measures able to support innovative research agendas. Nevertheless a knowledge based society, as the European Union aims to become, needs progressive and critical thinkers able to look beyond quick-fixes and who feel safe (academically) in challenging established practice, or mental models that actually contributed to create the problems in a first place.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2016.08.144.

Acknowledgement

The authors acknowledge funding as follows: RR work has been co-funded by the FP7-MC-IEF contract no. 255073 and by the Östersjöstiftelsen; DA has received funds from Slovene Human Resources Development and Scholarship Fund (grant no. 11011-28/2012-5). The authors thank all the respondents for the interviews and information they shared. We thank Silvia Lohfink for putting our pencil-made sketch into a nice Figure no.1. The authors have contributed as follows: RR has designed the study and wrote the paper, DA has collected data inclusive of the bibliographic search, administration and transcription of interviews and communication with the respondents throughout the process. Both have coded and analysed the data. Some of this data was used by DA in his MSc thesis. The findings and observations contained in this paper are those of the authors and do not reflect the views of the funding agencies, their departments of belonging, nor of the respondents.

References

Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E., Patton, E., 2011. Co-management and the co-production of knowledge: learning to adapt in Canada's Arctic. Glob. Environ. Chang. 21, 995–1004.
Becher, T., Trowler, P.R., 2001. Academic Tribes and Territories: Intellectual Enquiry and the Culture of Disciplines. Open University Press, Buckingham.
Bjurström, A., Polk, M., 2011. Climate change and interdisciplinarity: a co-citation analysis of IPCC third assessment report. Scientometrics 87, 525–550.
Boix Mansilla, V., Dawes Duraisingh, E., Miller, M.L., McAlpine, S., Rhodes, A., 2006. Integrating Disciplines to Deepen Understanding. A Framework for Design. Harvard University, Cambridge.
Bornmann, L., 2013. What is societal impact of research and how can it be assessed? A literature survey. J. Am. Soc. Inf. Sci. Technol. 64, 217–233.
Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D.J., Newig, J., Reinert, F., Abson, D.J., von Wehrden, H., 2013. A review of transdisciplinary research in sustainability science. Ecol. Econ. 92, 1–15.
Castree, N., Adams, W.M., Barry, J., Brockington, D., Buscher, B., Corbera, E., Demeritt, D., Duffy, R., Felt, U., Neves, K., Newell, P., Pellizzoni, L., Rigby, K., Robbins, P., Robin, L., Rose, D.B., Ross, A., Schlosberg, D., Sorlin, S., West, P., Whitehead, M., Wynne, B., 2014. Changing the intellectual climate. Nat. Clim. Change 4, 763–768.
Corbera, E., Calvet-Mir, L., Hughes, H., Paterson, M., 2015. Patterns of authorship in the IPCC working group III report. Nat. Clim. (Change advance online publication).
Dilling, L., Lemos, M.C., 2011. Creating usable science: opportunities and constraints for climate knowledge use and their implications for science policy. Glob. Environ. Chang. 21, 680–689.
Funtowicz, S.O., Ravetz, J.R., 1993. Science for the post-normal age. Futures 25, 739–755.
Good, B., Vermeulen, N., Tiefenthaler, B., Arnold, E., 2015. Counting quality? The Czech performance-based research funding system. Res. Eval. 24, 91–105.
Heberlein, T.A., 1988. Improving interdisciplinary research: integrating the social and natural sciences. Soc. Nat. Resour. 1, 5–16.

Hirsch Hadorn, G., Bradley, D., Pohl, C., Rist, S., Wiesmann, U., 2006. Implications of transdisciplinarity for sustainability research. Ecol. Econ. 60, 119–128.
Huutoniemi, K., Klein, J.T., Bruun, H., Hukkinen, J., 2010. Analyzing interdisciplinarity: typology and indicators. Res. Policy 39, 79–88.
Kastenhofer, K., Bechtold, U., Wilfing, H., 2011. Sustaining sustainability science: the role of established inter-disciplines. Ecol. Econ. 70, 835–843.
Klein, J.T., 1990. Interdisciplinarity: History, Theory, and Practice. Wayne State University Press, Detroit.
Klein, J.T., 1996. Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities. University Press of Virginia, Charlottesville.
Klein, J., 2004. Prospects for transdisciplinarity. Futures 36, 515–526.
Klein, J.T., 2008. Evaluation of interdisciplinary and transdisciplinary research: a literature review. Am. J. Prev. Med. 35, 116–S123.
Kozak, M., Bornmann, L., Leydesdorff, L., 2015. How have the Eastern European countries of the former Warsaw Pact developed since 1990? A bibliometric study. Scientometrics 102, 1101–1117.
Lotz-Sisitka, H., Ali, M.B., Mphepo, G., Chaves, M., Macintyre, T., Pesanayi, T., Wals, A., Mukute, M., Kronlid, D., Tran, D.T., Joon, D., McGarry, D., 2016. Co-designing research on transgressive learning in times of climate change. Curr. Opin. Environ. Sustain. 20, 50–55.
McNie, E.C., Parris, A., Sarewitz, D., 2016. Improving the public value of science: a typology to inform discussion, design and implementation of research. Res. Policy 45, 884–895.
Merton, R.K., 1968. The Matthew effect in science: the reward and communication systems of science are considered. Science 159, 56–63.
Palsson, G., Szerszynski, B., Sörlin, S., Marks, J., Avril, B., Crumley, C., Hackmann, H., Holm, P., Ingram, J., Kirman, A., Buendía, M.P., Weehuizen, R., 2013. Reconceptualizing the 'Anthropos' in the Anthropocene: integrating the social sciences and humanities in global environmental change research. Environ. Sci. Pol. 28, 3–13.
Plut, D., Spes, M., Brecko, V., 2001. Slovenia. In: Carter, F.W., Turnock, D. (Eds.), Environmental Problems of East Central Europe Routledge, New York.
Porter, A., Rafols, I., 2009. Is science becoming more interdisciplinary? Measuring and mapping six research fields over time. Scientometrics 81, 719–745.
Rodela, R., 2016. On the use of databases about research performance: comments on Karlovčec and Mladenić (2015) and others using the SICRIS database. Scientometrics 1–7.
Røpke, I., 2005. Trends in the development of ecological economics from the late 1980s to the early 2000s. Ecol. Econ. 55 (2), 262–290.
Rosenfield, P.L., 1992. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Soc. Sci. Med. 35, 1343–1357.
Simon, D., Schiemer, F., 2015. Crossing boundaries: complex systems, transdisciplinarity and applied impact agendas. Curr. Opin. Environ. Sustain. 12, 6–11.
Spangenberg, J., 2011. Sustainability science: a review, an analysis and some empirical lessons. Environ. Conserv. 38, 275–287.
Sugimoto, C.R., 2010. Looking across communicative genres: a call for inclusive indicators of interdisciplinarity. Scientometrics 86, 449–461.
Turner, V.K., Benessaiah, K., Warren, S., Iwaniec, D., 2015. Essential tensions in interdisciplinary scholarship: navigating challenges in affect, epistemologies, and structure in environment–society research centers. High. Educ. 70, 649–665.
UNESCO, 2010. UNESCO Science Report 2010.
van Rijnsoever, F.J., Hessels, L.K., 2011. Factors associated with disciplinary and interdisciplinary research collaboration. Res. Policy 40, 463–472.
Wagner, C.S., Roessner, J.D., Bobb, K., Klein, J.T., Boyack, K.W., Keyton, J., Rafols, I., Börner, K., 2011. Approaches to understanding and measuring interdisciplinary scientific research (IDR): a review of the literature. J. Inf. 5, 14–26.

Please cite this article as: Rodela, R., Alašević, D., Crossing disciplinary boundaries in environmental research: Interdisciplinary engagement across the Slovene research community, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.08.144