6 Skill development in collaborative research projects: A comparison between PhD students in multi-actor research programs and in traditional trajectories[22]

Abstract

The growing number of PhD students has spurred debates about the societal relevance of PhD training trajectories. The academic labour market does not provide enough jobs and many PhD graduates will have a career outside academia. It has been questioned whether current PhD training trajectories are still adequate and collaborative research projects are introduced as alternative trajectories. Such trajectories can support the development of a broader set of skills, but might have adverse effects on the development of academic skills. This article studies the effects of collaborative training trajectories on PhD skill development. We specifically focus on PhD students in multi-actor research programs (MARPs), an increasingly popular organizational form for facilitating transdisciplinary research activities. Using a survey among PhD students in MARPs and in traditional trajectories, we study the effects of a MARP on the development of four types of skills: (1) academic research skills, (2) academic communication skills, (3) translation and dissemination skills, and (4) transferable skills. Our findings suggest that collaborative training trajectories can indeed result in the development of a broader set of skills without negative effects on academic skill development. We conclude that collaborative research projects can be a viable alternative and identify three conditions for an optimal effect on PhD skill development.

6.1 Introduction

The number of PhD holders has been growing for decades, for example between 1998 and 2008 the worldwide number of yearly earned science doctorates grew by nearly 40% (Cyranoski et al. 2011). Of course, the academic labour market does not provide enough jobs for all those PhD graduates (Enders 2005; Mangematin 2000), and most will have a career outside academia (Borrell-Damian et al. 2010; LERU 2014). Although the share of PhD holders in a country's labour force is seen as an indicator for the development of a knowledge economy,

22 This chapter has submitted for publication by Higher Education as Wardenaar, Tjerk, Rosalie Belder, Marije de Goede, Edwin Horlings and Peter van den Besselaar, "Skill development in collaborative research projects: A comparison between PhD students in multi-actor research programs and in traditional trajectories"

it has been questioned whether current PhD training trajectories are still adequate (Campbell et al. 2005): Have PhD holders acquired the relevant skills during their training? The "new academic generation should be trained to become creative, critical and autonomous intellectual risk takers, pushing the boundaries of frontier research" (EuropeanCommission 2011), but the modern doctorate should also prepare students for careers beyond research and education (LERU 2014). Recent studies on skill development in PhD training trajectories are, in this respect, not uniformly positive (De Grande 2009; Manathunga et al. 2009).

The debate on the societal relevance of PhD trajectories has spurred interest in alternative PhD training trajectories. Many of these alternative trajectories are implemented with a belief that transdisciplinarity is essential for innovation and they induce collaborations with different disciplines and other sectors (Borrell-Damian et al. 2010; LERU 2014). Such collaborative trajectories can support the development of a broader set of skills (Harman 2002; Thune 2009, 2010). However, there is also evidence that a transdisciplinary approach in PhD projects poses difficulties for early career researchers (Felt et al. 2013), as non-research activities places additional burdens on PhD students (Borrell-Damian et al. 2010).

This article studies the effects of collaborative training trajectories on PhD skill development. We specifically focus on multi-actor research programs (MARPs), an increasingly popular organizational form for facilitating transdisciplinary research activities (Hessels et al. 2014; Lyall and Fletcher 2013). Using a survey among PhD students in MARPs and in traditional trajectories, we study the effects of a MARP on the development of four types of skills: (1) academic research skills, (2) academic communication skills, (3) translation and dissemination skills, and (4) transferable skills.

The rest of the paper is structured as follows. In section 6.2 we develop our theoretical framework. In section 6.3, we describe our survey and sample. The empirical results are presented in section 6.4. In section 6.5, we draw conclusions and discuss their implications.

6.2 Theoretical background

6.2.1 Skill development during the PhD trajectory

A PhD project is the training trajectory for an academic research career. PhD holders are best known for their analytical and technical skills and their ability to translate issues into research questions (Bogle et al. 2011). More recently, attention has shifted to the development of a broader set of skills, especially so-called transferable skills (Borrell-Damian et al. 2010). Transferable skills are defined as skills developed in one context (in this case the academic context) that are useful in other contexts, for example future employment whether that is in research, government or business (Scholz et al. 2009). Other concepts used in

the literature are professional skills and soft skills, but we use the concept of transferable skills because of its emphasis on the fact that these skills are learned in one context but can be used in another context. This fits exactly to what is at stake in this discussion, i.e. do PhD students obtain skills that can be useful in a non-academic context. Consensus about transferable skills for PhD students is lacking but most descriptions include project management, teamwork, and communication (EuropeanCommission 2011; LERU 2014; Metcalfe and Gray 2005; Scholz et al. 2009). [23]

It has been argued that PhD students already develop a broad set of skills in traditional trajectories (Bogle et al. 2011). Unemployment among PhD holders is only around 2% (Auriol et al. 2013; Enders 2002), indicating that employers value PhD holders. Other studies, however, stress that transferable skills of PhD students are similar to those of master students (De Grande 2009); that employers are not aware of the broader skillset of PhD holders (Borrell-Damian et al. 2010); and that a large share of PhD holders with jobs outside academia believe that their training has little or no added value for his or her current job (Manathunga et al. 2009).

Although the relationship between training context and skill development remains unclear, new PhD training trajectories are being introduced to develop a broader set of skills (LERU 2014). These new trajectories emphasise transdisciplinary collaboration with other disciplines and sectors. The ultimate aim of these trajectories is to increase the attractiveness of PhD holders for (non-academic) employers and to educate a cadre of PhD holders with ties to other sectors and professions (Gemme and Gingras 2012; Harman 2002; Thune 2009).

Participation in such a collaborative project during the PhD training may, like other experiences during this career phase, have strong and lasting effects on skill development and on future work and research practices of PhD students (Slaughter et al. 2002; Verbree 2011), effects that might affect their career steps after the PhD (Manathunga et al. 2012).

6.2.2 Multi-actor research programs

MARPs are large-scale research programs that bring together a diverse range of actors around a grand societal challenge with the intention of concentrating research activities and fostering relationships among participants (Hessels et al. 2014). These programs offer a different structure for PhD students, by defining conditions and criteria for participation, formulating expectations in its mission and objectives, having a particular audience, and involving a variety of participants. MARPs differ from traditional trajectories on at least four characteristics. First,

23 Research skills can in this respect also be transferable. After all, PhD holders often work in non-academic contexts that are knowledge and research intensive. However, to distinct between skills that have traditionally been associated with the PhD (especially research skills) and this broader set of skills, we follow the existing definitions of transferable skills.

PhD students are likely to have limited freedom to develop their project. MARPs have nested organizational structures (Klerkx and Leeuwis 2008; Wardenaar et al. 2014). Programmes are divided in broad subprograms with more specific aims; the actual work is done in smaller work packages and in individual projects (de Jong et al. 2012; Merkx et al. 2012). Project aims and research questions are hence defined before a PhD student starts working in the project. It should be noted, however, that this may also occur in more traditional research environments.

Second, PhD students in MARPs are more likely to be involved in interactions with non-academic stakeholders. MARPs bring together a diversity of participants around a certain theme or challenge (Hessels et al. 2014), with stakeholders in a variety of roles (Kloet et al. 2013; Roelofsen et al. 2011). It is argued that such frequent interactions and on-going dialogues between researchers and stakeholders increases the usability of science (Lemos and Morehouse 2005; Wardenaar et al. 2012).

Third, MARPs typically focus on grand societal challenges which do not follow the borders of academic disciplines, and interdisciplinary research is increasingly seen as essential in addressing these challenges (Lyall and Fletcher 2013; Millar 2013). PhD students in MARPs will therefore more often work in projects characterised by involvement of researchers with different disciplinary backgrounds.

Finally, PhD students in MARPs are likely to have a more society-oriented outlook, as MARPs serve multiple goals: On the one hand scientific advancement and on the other hand the development of practical solutions for societal problems (Hegger et al. 2012; Pohl 2008). These programs subsequently have a large emphasis on and production of societal output (Koier and Horlings under review).

6.2.3 Skill development in multi-actor research programs

Given the characteristics of MARPs, we expect participating PhD students to obtain a different set of skills than PhD students in traditional trajectories. The literature suggests two possible mechanisms that we will discuss below: (1) (self-) selection, and (2) socialization.

(Self-)selection

MARPs may attract a different type of PhD student than traditional trajectories. People do not randomly choose their work environment, but select organizations with characteristics that match their own (Schneider et al. 1995). In addition, MARPs need PhD students that can adapt to their objectives and work practices. Several individual characteristics may affect the (self-)selection of PhD students.

Personality traits – PhD students who prefer the specific context of a MARP may have a stronger interest in research focusing on societal problems. And MARPs need PhD students who are able to adapt to the broader goals of the program and are open to different types of collaborations. This requires proactive and

open-minded people, who are relatively unconstrained by situational forces (Briscoe et al. 2006; Seibert et al. 1999).

Experience – PhD students presumably select (and are selected by) a PhD program based on their personal characteristics as well as on an expected match with their skills and abilities. Hence, MARPs provide the context for developing certain skills, but also attract students that already own these skills and look for a place to apply them.

Socialization

After joining a MARP, the PhD student will be involved in different processes and activities. It is likely that such socialization affects skill development. In this part, we describe several characteristics of MARPs and formulate expectations about how these characteristics affect skill development.

Working with predefined research questions and within large teams can hinder PhD students to take full responsibility for their project. This would run against the belief that PhD students should take responsibility at an early stage for a project's scope, direction and progress (EuropeanCommission 2011). In the case that PhD students are indeed hindered to take responsibility, limited freedom to develop their own project is expected to have negative effects on the development of academic skills.

Involvement of heterogeneous partners enriches the knowledge base and brings together a diversity of values, incentives, and practices. Various studies have drawn attention to the obstacles such projects raise for individual researchers (Butcher and Jeffrey 2007; Felt et al. 2013). Other studies indicate, however, that PhD students are more open and able to adapt to this type of boundary-crossing research (Gardner et al. 2013). We expect that stakeholder involvement can have positive effects on non-research skills like communication but negative effects on the development of academic (research) skills.

The involvement of researchers from different disciplinary backgrounds are expected to have similar effects on the development of non-research skills as the effects of involvement of stakeholders. With respect to academic skills, interdisciplinary research was long considered harmful for an individual's academic career. However, recent studies show that this is changing (Millar 2013; Sobey et al. 2013). Interdisciplinary research is increasingly seen as a condition for early career researchers to develop independency (Bogle et al. 2011). We therefore expect that the involvement of researchers from different disciplinary backgrounds in MARPs help PhD students to develop both their academic and broader skills.

Finally, translating research findings into societally relevant output requires a concerted effort (Ford et al. 2013). Time and efforts spent on societal output may go at the expense of time and efforts spent on research, while it has been

argued that a very research intensive period in the early career phase is essential if one wants to become an independent researcher (Laudel and Gläser 2008). We expect that translation and dissemination activities have positive effect on the development of (non-academic) communication skills but negative effects on academic skill development.

To summarize, MARPs provide PhD students a working environment that is different from traditional trajectories. We expect that participating PhD students obtain a different set of skills, either through (self-)selection or socialization. We raise the following three specific questions to test our expectations:

1. *Is the set of skills developed by PhD students in multi-actor research programs different from the set of skills developed by PhD students in traditional trajectories?*
2. *Are differences between training trajectories in skill development related to individual characteristics and to training context?*
3. *What is the relationship between individual characteristics and training context characteristics and the development of different types of skill?*

6.3 Methodology

6.3.1 Method and data

Our study focuses on training trajectories of PhD students in sustainability research. Studies of sustainability programs show a strong emphasis on inter- or transdisciplinarity (Hegger et al. 2012; Pohl 2008). Our analysis requires comparison of PhD students in a MARP with PhD students in a traditional trajectory. Given that no two MARPs are the same, that the context of a specific MARPs may affect skill development, and that countries rarely have more than one large-scale MARP in sustainability research, we compare MARP trajectories and traditional trajectories in two countries, the Netherlands and the UK. This also allows us to study international differences in skill development. Our sample consequently comprises four groups of PhD students.

We started the selection of respondents with participants of two MARPs: Knowledge for Climate (the Netherlands)[24] and the Tyndall Centre (UK)[25], which have ambitious transdisciplinary approaches and large numbers of PhD students (Wardenaar 2013). The programs provided us with background information and contact details of participants. PhD students in traditional environments were found by identifying non-MARP PhD students from the same home institutions and scientific specializations as the MARP PhD students. The total population consists of 415 PhD students: 152 from the Netherlands and 263 from the UK.

24 www.klimaatonderzoeknederland.nl
25 www.tyndall.ac.uk

Surveys were distributed and data were gathered by a specialized organization under the supervision of the researchers. The response rate in the Dutch group was 61% (n=93), the response rate in the British group was 33% (n=86). The British response rate is significantly lower, because the contact information of the UK sample turned out to be less up-to-date. Respondents were asked to indicate whether they were in a traditional or a MARP training trajectory. Their response was used to create four groups (table 6.1). Although we aimed for respondents in their second year or later, some first-year PhD students (n=12) did fill out the questionnaire. These respondents were excluded because they may have only just started and may not have had the opportunity to grasp the context of their project.

Table 6.1 Overview of respondents per group

	MARP	Traditional trajectory	Total
Netherlands	40	47	87
United Kingdom	37	43	80
Total	77	90	167

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6.3.2 Skill development

The dependent variable of this study is skill development. The literature does not provide a standard categorization of skill types. From available categorizations (Metcalfe and Gray 2005; Precision 2007; Scholz et al. 2009; Vitae 2010), we selected 21 skills, either because they were mentioned in (almost) every categorization or because they are especially relevant to collaborating with non-academic stakeholders. For every skill, respondents were asked to indicate on a scale from 1 (no experience) to 7 (excellent) their present level, and their level at the start of their PhD studies.[26] Using factor analysis the 21 skills were classified into four groups:

1. **Academic research skills**: seven skills needed to work as an independent researcher, namely the ability to (1) formulate a good research question, (2) apply properly research methods and techniques, (3) link own work to relevant theories within academic specialization, (4) develop and maintain relations with colleagues in the wider research community (5) work independently, (6) show leadership and (7) reason analytically. This group fits neatly with the set of skills that is traditionally associated with a PhD trajectory (LERU 2014). The reliability of the scale in the current study was $\alpha = .79$.

26 When respondents indicated that they presently had no experience with a certain skill, while they also indicated they had some level of that skill at the start of their PhD, we considered the values as missing.

2. **Academic communication skills**: four skills researchers need to make themselves visible within the academic community, namely to (1) get articles published, (2) review academic work, (3) write proposals for funding or grants, and (4) keep up-to-date on developments in your academic specialization. Becoming visible is essential for early career researchers to gain recognition and become a full member of the research community (Åkerlind 2008). The reliability of the scale in the current study was α = .74.

3. **Translation and dissemination skills**: six skills needed to explain and transfer knowledge to non-academic stakeholders, namely to (1) present findings to a non-academic audience, (2) contribute to public debates related to research topics, (3) support the education of professionals, (4) get findings implemented outside the academic world, (5) develop and maintain work relations with people from government, and (6) develop and maintain work relations with people from industry/business. These skills fit within the definition of transferable skills, but due to their explicit emphasis on non-academic communication we labeled them as translation & dissemination skills. The reliability of the scale in the current study was α = .74.

4. **Transferable skills:** four skills that are required to work at an advanced level in any organization namely to (1) manage a project, (2) take initiative, (3) work in a team with a division of tasks, and (4) work with targets defined by the management or senior staff. The reliability of the scale in the current study was α = .65.

6.3.3 Measuring characteristics of individual participants and training contexts

Personality

We assessed whether a PhD student has (1) a proactive personality and (2) a boundaryless mindset. The proactive personality scale (Seibert et al. 1999) includes four items such as: 'I am always looking for better ways to do things'. The reliability of the scale in the current study was α = .66. A boundaryless mindset (Briscoe et al. 2006) was assessed with four items such as: 'I am energized by new experiences and situations'. All items are measured on a 5-point Likert-scale ranging from (1) 'little or no extent' to (5) 'a great extent'. The reliability of the scale in the current study was α = .78.

Experience

PhD students presumably select a PhD program based on their personal characteristics but also on an expected match with their skills and abilities. We therefore specifically examine the starting level of the four skill types.

Freedom to develop own project:
The freedom to develop one's own project was measured based on contribution to the PhD research proposal, using two survey questions: (1) what was the status of the research proposal at the start of the project? and (2) who wrote the main part of the research proposal? Three categories were distinguished. Low influence: the project proposal was developed before the start of the project by somebody other than the PhD student; medium influence: the project proposal was developed during the project by somebody other than the PhD student as main author; and high influence: the PhD student developed the main part of the project proposal before or during the project.

Multidisciplinary context
MARPs have multi- or interdisciplinary compositions. We focus on multidisciplinarity because interdisciplinarity is difficult to measure by means of a questionnaire (Millar 2013). We developed a straightforward variable using two survey questions: (1) in which field(s) of research are you working and (2) in which field(s) of research are the academic researchers you work with working. Respondents were provided a list of research fields based on the Survey of Earned Doctorates (NORC 2011), consisting of those categories and subcategories relevant for the respondents' specializations. The variable multidisciplinary consists of three categories: (1) monodisciplinary: the PhD student and his or her colleagues work in one and the same research field, (2) multidisciplinary influences: the PhD student works in one research field and the colleagues in several research fields, and (3) multidisciplinary approach: the PhD student and his or her colleagues all work in more than one research field.

Stakeholder involvement
Non-academic stakeholders do not have a self-evident role in academic research and may be involved in different research phases (de Jong et al. 2011). To assess stakeholder involvement in a PhD student's project we asked about stakeholder influence in five research phases: formulating research questions, setting up research design, doing the actual research, discussing and interpreting outcomes, and communicating outcomes. The answer categories were 5-point scales ranging from 'little or no influence' to 'a great influence'. The average of these scores was taken as the indicator for stakeholder involvement.

Society-oriented outlook
To assess the extent to which a PhD student has a society-oriented outlook, we asked respondents about their activities and outputs. Subsequently we constructed three variables: (1) society-oriented activities, (2) society-oriented output, and (3) academic outlook. Society-oriented activities counts the number of times a PhD was involved in activities like attending policy, industry or business meetings. Society-oriented output counts the number of non-academic publications and presentations that resulted from a respondent's project.

Academic outlook is a control variable and combines both the number of times a PhD was involved in academic activities (e.g. attending a scientific conference) and the number of academic output that resulted from a respondent's project (e.g. a written publication for a scientific audience).

Supervision and teaching
Existing literature on MARPs do not discuss supervision of PhD students or teaching activities performed by PhD students. Previous studies on skill and career development of early career researchers show that these are crucial aspects (Butcher and Jeffrey 2007; Mainhard et al. 2009; Scaffidi and Berman 2011), which is why we include them in our analysis.

Supervision was assessed by asking the respondents to what extent they agree with 11 statements about their supervisor(s) using a 5-point Likert-scale ranging from (1) 'little or no extent' to (5) 'a great extent'. An example of a statement is 'My academic supervisor provides direct assessments of my progress'. Factor analysis identified three different dimensions of supervision: narrow (focused on research) (6 items, $\alpha = .86$), broad (focused on careers) (3 items, $\alpha = .76$) and network (focused on collaboration and networking outside academia) (2 items, $\alpha = .53$).

To make an assessment of the importance of teaching, we asked respondent to indicate in percentages the amount of working time they spend on teaching during the PhD project.

6.3.4 Comparing groups
The results with respect to skill levels, individual characteristics and training contexts are compared using independent samples tests (ANOVA). Kolmogorov-Smirnov tests show that in most cases data are normally distributed. The ANOVA tests for academic research skills, society-oriented activities and output, and supervision network does not meet the criterion of homogeneity of variance (Levene's test). Separate analyses using non-parametric Kruskal-Wallis tests for all comparisons between the groups produce the same results as the ANOVA tests. In order to make the results comparable, in the next section we present only the results of the ANOVA tests. Post hoc tests are used to find differences between specific pairs of groups, using the Ryan-Einot-Gabriel-Welsch Q procedure.

6.4 Empirical findings
In this section, we first analyze skill development in the four distinguished groups. Second, we compare individual characteristics and training context between the groups. Finally, we analyze how skill development is related to both characteristics of individual participants and the training context.

6.4.1 Differences in skill development
We expect the set of skills developed by PhD students in MARPs to be different

from the skills developed by PhD students in traditional trajectories. Table 6.2 summarizes our findings with respect to current skill levels.

Table 6.2 Current skill levels

			Current skill level			
			Academic research	Academic communication	Translation & Dissemination	Transferable
Netherlands	MARP	Mean	4.93	4.00	3.65	4.63
	N = 40	Sd.	.81	1.24	1.33	.99
	Traditional	Mean	4.92	4.00	3.23	4.32
	N = 47	Sd.	1.14	1.26	1.38	1.25
UK	MARP	Mean	5.54	4.01	3.76	5.41
	N = 37	Sd.	.78	1.31	1.36	1.26
	Traditional	Mean	5.28	4.00	3.07	4.99
	N = 43	Sd.	.77	1.22	1.42	1.27
ANOVA		df Between	3	3	3	3
		df Within	163	163	163	163
		F	4.517	.001	2.330	6.317
		Sig.	.005	1.000	.076	.000

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The results show that PhD students in MARPs do not report lower academic research skills or academic communication skills. Post hoc tests show that the British MARP group reports significant higher academic research skills than the two Dutch groups. The MARP groups report, as expected, higher non-academic skills than their national counterpart. However, the groups are only significantly different in the level of transferable skills. Post hoc tests show that UK MARP PhD students report significant higher transferable skills than the groups from the Netherlands and that the traditional group from the UK report significant higher skills than the traditional group from the Netherlands.

The comparison of PhD groups reveals some differences in skill levels of PhD students in MARP and traditional training trajectories. Results with respect to translation and dissemination skills and transferable skills confirm our expectations, while results for academic skills are contrary to what we expected. Differences between groups are small and not always significant however. These results mean that either our assumptions about MARPs were wrong or that other variables should be taken into account which have different effects on skill

development. We subsequently take a closer look at the differences between groups in terms of characteristics of participants and training contexts.

6.4.2 A comparison of participants and their training contexts

Differences between PhD students in MARP and traditional training trajectories may have their origins in (self-)selection (the characteristics of participants) and in socialization (the training context). Do MARPs attract a different type of PhD student?

Table 6.3 Individual characteristics

			Personality type		Skill level at start of PhD			
			Bound.less	Pro-active	Aca-demic research	Academic. Com-munic.	Trans-lation & dissemi-nation	Trans-ferable
Nether-lands	MARP	Mean	3.98	3.90	3.88	2.28	2.77	4.00
	N = 40	St. dev.	.66	.60	1.01	1.06	1.32	1.18
	Traditional	Mean	3.86	3.90	3.89	2.59	2.44	3.70
	N = 47	St. dev.	.70	.60	1.15	1.12	1.16	1.28
UK	MARP	Mean	4.32	4.14	4.30	2.36	2.95	4.87
	N = 37	St. dev.	.52	.64	1.07	.93	1.51	1.37
	Traditional	Mean	3.92	4.05	4.08	2.30	2.37	4.25
	N = 43	St. dev.	.76	.62	.98	.86	1.24	1.41
ANOVA		df Between	3	3	3	3	3	3
		df Within	163	163	163	163	163	163
		F	3.643	1.457	1.398	.890	1.807	5.780
		Sig.	.014	.228	.245	.448	.148	.001

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The results in table 6.3 indicate that some form of (self-)selection does occur. PhD students in MARP groups score higher than their national counterpart on boundaryless mindset, which is associated with working across boundaries and neatly fits the objectives of MARPs. PhD students in the MARP groups have higher initial levels of translation and dissemination skills and transferable skills than the traditional groups. Post hoc tests show that the UK MARP group has a significant stronger boundaryless mindset and higher initial transferable skills than the British and Dutch traditional groups.

The results in table 6.4 show that there are some differences between the four groups of PhD students on the freedom to develop their own project. Other than

expected, differences between the two Dutch trajectories are small, while PhD students in the British MARP group have more freedom to develop their own project than their colleagues working in traditional arrangements. As expected, PhD students in MARPs work significantly more often in multidisciplinary research contexts (Chi-square = 17,78, p = .007).

Table 6.4 Training context characteristics (part 1)

		Netherlands		UK	
		MARP	Traditional	MARP	Traditional
N		40	47	40	43
Freedom	Low	10%	13%	8%	14%
	Medium	25%	19%	25%	35%
	High	65%	68%	67%	51%
Multidisciplinary	Monodisciplinary	32%	52%	9%	40%
	Multidisciplinary influences	19%	19%	31%	23%
	Multidisciplinary approach	49%	29%	60%	37%

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The results in table 6.5 confirm our expectations that in both countries PhD students in MARP groups have more stakeholder involvement, are more involved in society-oriented activities, and – in the Dutch case – produce more society-oriented output.

Table 6.5 Training context characteristics (part 2)

			Stakeholder involvement	Society-oriented		Academic outlook
				Activities	Output	
Netherlands	MARP	Mean	1.78	11.35	10.25	21.55
	N = 40	St. dev.	1.10	5.87	4.99	5.93
	Traditional	Mean	.98	6.85	6.83	20.36
	N = 47	St. dev.	1.21	4.10	3.03	6.20
UK	MARP	Mean	.95	7.19	5.84	18.95
	N = 37	St. dev.	1.10	4.04	2.30	5.65
	Traditional	Mean	.88	6.93	6.58	18.56
	N = 43	St. dev.	1.20	4.29	3.19	5.06
ANOVA		df Between	3	3	3	3
		df Within	163	163	163	163
		F	5.369	9.136	12.400	2.330
		Sig.	.002	.000	.000	.076

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It should be noted, however, that the Dutch MARP group stands out, while differences between British groups are small. This is confirmed by the post hoc test. Differences in academic outlook are small, and do reveal that the strong society-oriented outlook of MARP PhD students is an addition to, rather than a substitution, for an academic outlook.

A comparison of supervision and the amount of time spent on teaching (table 6.6) shows that in both countries PhD students in traditional trajectories are more positive on supervision, but that supervisors in MARPs have better networks and collaboration experience. PhD students in the UK groups are more positive about supervision than PhD students in the Dutch groups. Post hoc tests confirm that traditional trajectories in the UK report more positive on narrow supervision than MARP trajectories in either country. Differences in teaching activities are minor and not significant.

Table 6.6 Training context characteristics (part 3)

			Supervision			Teaching
			Narrow	Broad	Network	
Netherlands	MARP	Mean	3.08	2.76	3.84	2.18
	N = 40	St. dev.	.83	.93	.91	1.08
	Traditional	Mean	3.37	2.94	3.78	2.23
	N = 47	St. dev.	.80	.93	.99	1.11
UK	MARP	Mean	3.17	2.93	4.19	2.05
	N = 37	St. dev.	.85	1.04	.87	1.05
	Traditional	Mean	3.63	2.98	4.02	2.05
	N = 43	St. dev.	.82	1.13	.66	.98
ANOVA		df Between	3	3	3	3
		df Within	163	163	163	163
		F	3.647	.373	1.880	.329
		Sig.	.014	.773	.135	.804

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To summarize, there are differences among the four groups in individual and training context characteristics. Post hoc tests do not reveal a sharp delineation between trajectories – only on interdisciplinarity – but do reveal differences between specific groups. The PhD students in the British MARP group stand out with a significant stronger boundaryless mindset and higher initial transferable skills. The Dutch MARP group PhD students are significant more active in transdisciplinary activities: they have stronger stakeholder involvement, undertake more society-oriented activities, and produce more society-oriented output. Important to note with respect to individual and training context characteristics is that the reported standard deviations show that differences within groups can be rather large. The variance within and between MARP groups indicate that these programs are less uniform than we initially presumed.

6.4.3 Explaining the development of different types of skill

Skills, personal characteristics, and training context are interrelated: Training context provides opportunities to develop skills; individual characteristics enable some persons to exploit such opportunities better than others; and the different characteristics can have contrary effects. In this section, we explore these interrelationships in a multivariate model. Table 6.7 presents the results of backward linear regressions using the development of the four skill types as the dependent variable and the various personal characteristics and aspects of the training context as independent variables.

Table 6.7 Backward linear regression models for skill development (standardized coefficients; *=p<.10, **=p<.05, ***=p<.01)

	Variables	Academic research	Academic communication	Translation & dissemination	Transferable
Personal	Start level specific skill	.582*** (10,810)	.405*** (6,976)	.584*** (11,955)	.713*** (14,814)
	Boundaryless mindset	.218*** (3,981)		.157*** (3,405)	
	Proactive attitude		.147** (2,512)		.147*** (3,120)
Context	British science system	.142*** (2,706)			
	Multidisciplinary			.090** (2,044)	.136*** (3,058)
	Stakeholder involvement		.095* (1,685)	.174*** (3,527)	
	Society-oriented outlook[27]			.194*** (3,914)	
	Academic outlook	.154*** (2,832)	.426*** (7,216)		
	Teaching		.107* (1,877)		
	Supervision	.094* (1,868)		.093** (2,099)	.156*** (3,505)
Model	R2	.629	.535	.720	.708
	R2 adjusted	.616	.519	.708	.700
	F	51,106	34,690	64,169	92,014
	(p)	(.000)	(.000)	(.000)	(.000)
	Valid N	167	167	167	167

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The models in table 6.7 are strong (high R2) and generalizable (adjusted R2 is close to unadjusted R2). Initial skill levels explain most of the variance. Supervision makes a modest contribution but not to academic communication skills. A multidisciplinary context is only conducive to non-academic skills, while academic outlook is only conducive to academic skills. Stakeholder involvement and society-oriented outlook support the development of translation and dissemination skills, but have – contrary to expectations – no negative associations with academic research skills. Conducting your PhD project in the British science system makes a significant contribution to academic research skills.

27 Society-oriented outlook consists of both society-oriented activities and society-oriented output.

Academic research skills
Table 6.7 reveals that supervision – lower in MARP groups – contributes positively to academic research skills. That we didn't find in section 6.4.1 the expected negative effect on academic research skills for the MARP PhD groups, is due to the positive effects of the other relevant variables: Boundaryless mindset (more often found in the MARP groups), current skill level and academic outlook (no significant differences between MARP and traditional groups). Finally, the positive effect of conducting a PhD in the British science system confirms the differences between the groups from the Netherlands and the U.K. found in section 6.4.1.

Academic communication
The backward linear regression also provides an explanation for the lack of difference between the groups on academic communication skills. Skill level at the start, proactive attitude, and academic outlook make the main contributions to development of academic communication skills. As discussed in section 6.4.2 traditional and MARP groups do not differ significantly on these characteristics. Stakeholder involvement and teaching make minor contributions.

Dissemination & translation skills
The MARP groups developed more translation and dissemination skills. Table 6.7 reveals that skill level at the start, boundaryless mindset, multidisciplinary approach, stakeholder involvement, society-oriented outlook, and supervision all contribute significantly to the development of these skills. The MARP groups score better on all these characteristics expect for supervision and in the British MARP group society-oriented outlook.

Transferable skills
Development of transferable skills in a PhD trajectory is to a large extent explained by the level of transferable skills at the start. This possibly explains best the differences between PhD students in MARP and traditional trajectories. Other variables that contribute are proactive attitude (no differences between MARP and traditional groups), multidisciplinary approach (higher in MARP groups), and supervision (lower in MARP groups).

6.5 Conclusions and discussion

This study contributes to the understanding of the effects of collaborative training trajectories on PhD skill development. A comparison of skill development in MARPs and traditional trajectories in the UK and the Netherlands reveals no differences in academic skills but slightly higher dissemination and translation skills and transferable skills in MARP groups (section 6.4.1). A closer look into individual and context characteristics of PhD students in the two trajectories (section 6.4.2) shows that MARPs attract PhD students that have a more boundaryless mindset, and a broader set of skills at the start of their project, and that they work in a more multi- and transdisciplinary research context. Differences within and between MARP groups on context characteristics indicate, however,

that these collaborative training trajectories are not uniform trajectories. Multivariate analysis (section 6.4.3) shows that the individual and context characteristics of training trajectories are a good explanation for the differences and similarities between the four groups in skill development (section 6.4.3). Especially the skill level before the start of the PhD trajectory is important, suggesting that activities before the PhD are essential in shaping the skill profile of PhD holders.

Our study has several limitations that provide directions for future research. First, time and resource constraints forced us to limit the scope of our study to one scientific field (sustainability research) and two countries (UK and the Netherlands). Sustainability research has a rich history of transdisciplinarity, also in traditional research modes. This may imply that the differences between the MARP and traditional trajectory groups are underestimated. By comparing the Netherlands and the UK we can better distinguish the effects of a MARP from the specifics of the science system. However, both countries have well-developed science systems that are relatively open to change. A general understanding of the effects of different training trajectories would need the study of scientific fields with less transdisciplinary experience as well as of training trajectories in more traditional science systems (e.g. Germany) and in emerging science systems (e.g. China, Brazil, India). Second, variance within and between research teams within MARPs is large. A better understanding of how MARPs translate their challenge-driven approach into training trajectories will strengthen our understanding of skill development in the context of collaborative projects. More in-depth analysis of functioning of MARPs is consequently required.

Our study reveals that collaborative PhD training trajectories have different effects on skill development than traditional trajectories. As we didn't find the expected negative effect on academic skill development, we believe that participation in a collaborative research project can result in a broader set of skills. However, an optimal effect of collaborative training trajectories on skill development depends on three conditions:

One, organizers of collaborative research programs (MARPs, universities, etc.) should be aware that participation in a collaborative training trajectory does not automatically result in the development of a broader set of skills. PhD students should be exposed to and participate in actual multi- and transdisciplinary processes. The variance within studied MARP groups in training context characteristics reveals that at present this is not the case. Program managers must make a concerted effort to create a context that is conducive to the skill development of individual PhD students.

Two, academic activities and output remain central in every PhD training trajectory. The development of a broader set of skills depends on involvement in both academic and society-oriented activities and processes. PhD students in the

studied MARP groups develop a broader set of skills because their challenge-driven approach is an addition to, rather than a substitution for, an academic outlook. PhD students and their supervisors should be aware of and guard the balance between these different activities. Our findings suggest that in the cases studied they are – as the academic performance does not suffer from the societal activities.

Three, personal characteristics should get a more prominent role in the hiring procedures of PhD students. Most of the variance in skill development is explained by initial skill levels, boundaryless mindset and proactive attitude. If focus in hiring PhD students would be mainly on cognitive capacity and academic research skills, this may hinder the development of transferable skills. A broad focus in hiring procedures – especially for collaborative training trajectories – will identify not only the students that are best for the job, but also signal early-on aspects of individual students that require additional attention and support.

To conclude, our findings suggest that collaborative training trajectories can indeed result in the development of a broader set of skills. These trajectories can be seen as a viable alternative to traditional trajectories. Collaborative training trajectories that meet the mentioned conditions are a reasonable response to the criticism on the lack of societal relevance for educating ever increasing numbers of PhD holders.

Acknowledgements

We would like to thank Kees Brammer and Paco Lim for their contribution to data collection. The authors wish to thank Stefan de Jong en Elizabeth Koier for their valuable comments on an early draft of this paper. Finally, we are very grateful for the helpful collaboration of Monique Sleegers and Peter Driessen (Knowledge for Climate) and Asher Minns (Tyndall Centre).

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