Which skills? A critical perspective on the skills facilitating the transfer of third-cycle students to knowledge-intensive SMEs

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***Abstract*—This Research Full Paper relates to public-private innovation ecosystems. This loosely knit form of cooperation allows for beneficial activities such as knowledge transfer, dissemination of novel technology, and recruitment. In these contexts students graduating from third-cycle education should be able to find opportunities for transferring to knowledge-intensive positions in small and medium-sized enterprises (SMEs).**

However, a 3-year study of the reasons why firms approach public organisations within a Europe-wide, public-private innovation ecosystem suggests that students might struggle to find such opportunities. Through a questionnaire provided to all firms approaching the ecosystem we identify recruitment as one of their lowest ranked interests. By interviewing members of the public organisations found in the ecosystem we identify how cooperation is initiated and maintained, and how this influences the opportunities for students to transfer into industry. The results provide nuance to the current emphasis in skill development within third-cycle (engineering) education. It is rarely recognized that fostering technical skill and academic entrepreneurship might not be enough to allow all types and sizes of firms to receive engineering students.

Particularly, this study identifies the academic and industrial boundary spanning roles at knowledge-intensive SMEs as important. These roles require a third-cycle education that early on hones skills that typically do not become critical until much later for students that pursue an academic path – e.g., the inter-organisational project management skills necessary to effectively seek research funding or to negotiate goal alignment between organisations. We argue that to allow third-cycle students to practice the finer points of such skills, universities need to evolve more distributed support structures for innovation that integrate in-depth engineering knowledge with innovation skills and have an increased focus on human and social capital.

I. Introduction

The last few decades have seen a change to the relationship between academia and industry, which is affecting the activities of both academic researchers and organisations [1]. A substantial number of academic researchers are now involved in the "third mission" [2], i.e., a part of their scholarly activities involve providing "services" to both academia and the wider society. As part of these services, such as technology transfer, academic organisations are becoming involved in public-private innovation ecosystems [3], [4], [5]. These are sets of public and private organizations that incorporate both production and use side participants, and which interconnect, often around a focal firm or a platform, to focus on the development of new value through innovation [6]. In other words, academia's exposure to industry is growing, and especially so the exposure of the applied sciences to smaller enterprises as public policy attempts to support job growth in this segment [7].

Arguably, this should increase the opportunities for engineering students in third-cycle education to transfer to knowledge-intensive positions in industry. However, this context is substantially different from that experienced by the PhD who transfers to a large research-focused company, initiates a university spin-off, or sets up a start-up. Unfortunately, as the higher levels of education are understudied [8], the skills required for successfully managing an early career at the border of a loosely knit academia and industry are not well known.

Therefore, this paper presents a study of small and medium-sized enterprises (SMEs) involving themselves in a public-private innovation ecosystem. The aim is to elicit their motivation and the conditions for this involvement. The purpose of the study to thus clarify what skills could help an early-career PhD seeking to transfer to SMEs in this context.

II. Theoretical Background

The concept of *innovation ecosystems* that aim for value creation is rather new [1], and overlaps with other types of loosely coupled sets of public and private organisations. Academic organisations are typically more prominent in *knowledge ecosystems* centred on knowledge generation, while industry is dominant in *business ecosystems* that mainly work towards value capture [9], [10]. Academic organisations can become leaders in innovation ecosystems in case industry is reluctant to take on this role, but usually rather act as advisers [3], [4].

On the one hand, cooperation between public and private organisations can often experience difficulties due to cultural differences. These difficulties might not be possible to overcome until substantial trust has been created [11], [12], which might take more time in loosely coupled cooperation. On the other hand, firms might be vary of investing too heavily in collaboration with academia, as this might decrease the value of simultaneous, heavy investments in internal scientific research [13]. Loosely coupled cooperation might then be appreciated as it allows partners to take stock of each other before committing fully. Innovation ecosystems are thus likely conducive to collaboration models in which firms e.g., wait with engaging in research and rather set up collaboration suitable for second-cycle capstone or thesis courses [12], [14]. In this way firms combine the best of two worlds as they get tailor-made advice on how to use cutting-edge technology [15], [16] without spending a large effort themselves [17]. While academia ideally wants to engage on research, this way of also enabling second-cycle students to learn from best practice in an industrial context is increasingly appreciated in education [18], [19]. A primary reason is that it offers engineering students an opportunity to learn informal engineering skills. Although these skills are otherwise difficult to teach in higher education, the engineering discipline of a (second-cycle) engineering student can come with the expectation to quickly master such skills [20]. This cooperation also aligns well with strong contemporary initiatives such as CDIO [21], which seek to define best practice in the context of engineering education. This includes emphasising professional skills taught in close cooperation with industry.

However, not all second-cycle students will have the necessary skills to seamlessly fulfill requirements from both academia and industry. Particularly, when a firm wants to make use of student placements to explore what is, to them, unknown technology, it might require students who are accomplished boundary spanners [17]. In other words, students who are able to bridge boundaries, in this case organisational boundaries between academia and industry, to bring together distinct networks and expectations [22]. This is to be expected as this technological brokering, also when occurring in industry, typically requires much resources [23], individuals with both deep technical know-how and extensive communication skills [24], and even employees who occupy special places in the organisational networks [25]. As third-cycle students also have academic requirements to fulfill, they will face similar challenges when addressing industrial requirements - especially if these are formed in the context of value creation and technology brokering. Arguably, if third-cycle students then transfer into early industrial careers in a public-private innovation ecosystem, such requirements can easily accompany their new roles. Maintaining a collaboration with former colleagues can be a necessity to access, enable cost-savings related to or even push research in a direction required for future growth [16].

Still, studies on third-cycle engineering students and the transfer to small knowledge-intensive, engineering firms have rather focused on the establishment of spin-offs by academic researchers. The primary choices and activities to enable this *academic entrepreneurship* can be driven by the third-cycle students themselves [26]. That the academic context is not conducive to commercialization can then lead to many challenges, including conflict with advisors based on differences in expectations and the need to overcome a lack of business and management skills [26], [27]. Successfully overcoming these challenges are often tied to personal motivation and interests. Therefore, while universities can do more to support the skill development of third-cycle students interested in academic entrepreneurship, it will still not be for everyone. This suggests that other paths to transfer into an early career at knowledge-intensive SMEs should also be investigated.

III. Methodology

This study was conducted through a questionnaire and interviews. The associated steps involving data collection and analysis are described separately in this section.

A. The Questionnaire

The questionnaire was administered to SMEs that approached the Digital Innovation Hubs and Collaborative Platform for Cyber-Physical Systems (HUBCAP) project [28] during its open calls for collaboration between 2020 and 2022. This was a substantial amount of SMEs from across Europe, as HUBCAP aims at building a pan-European innovation ecosystem by connecting hubs for SME support in the cyber-physical systems (CPS) domains.

1) Data Collection: The study started by clarifying the purpose of the questionnaire and interviews [29]. This purpose was then operationalised into features that could be measured, resulting in a semi-structured questionnaire with questions related to this study. To check the clarity of the questionnaire and elicit associated feedback [30] it was piloted with 2 project partners before being deployed. All project partners were then invited to identify and comment on any remaining issues.

The final set of questions included a few open-ended questions for the sake of validity, but centred on four sets of multiple questions to be graded on a 7 point Likert scale from "No Interest" to "High Interest". Each set asked for the SMEs' interest in HUBCAP regarding different aspects of scholarly service. First from the perspective of relevant application domains, and then in regard to relevant scientific disciplines, that the SMEs were either strong or weak in.

The questionnaire was clearly indicated as voluntary, both through a written statement and by its isolation into a visually distinct and separate addition to the registration process when approaching HUBCAP. The respondents could withdraw at any part of the questionnaire and leave parts of it unanswered. Still, after all open calls had closed the questionnaire had been opened by representatives from 170 SMEs out of the 234 who registered. Most of these representatives opted to answer all questions. This meant that the response rate was overall 73%. The response rate for each question is reported in the results.

2) Data Analysis: The questionnaire asked the SMEs to name relevant application domains and scientific disciplines. This was used to validate that all SMEs were active in CPS domains. Naturally, not all SMEs were comfortable with naming relevant application domains and scientific disciplines, as it could hint at their future market strategy. However, those who did not name domains or disciplines were very few. Furthermore, we could compare answers to each open-ended question with those to each set of Likert scale questions to ensure that companies were not simply clicking their way through the questionnaire without much thought.

The summary of the responses to the 7 point Likert scale questions are provided in Section IV.

B. The Interviews

The interviews targeted the project partners of the HUBCAP project which were setting up digital innovation hubs (DIHs) to act as one-stop-shops for supporting SMEs. These were five universities and three research institutes. Senior people covering one or several of three activities were sought: management of innovation or research projects; research studies; and provision of innovation support.

1) Data Collection: Based on the purpose of the study, the interviews were thematised and interview questions defined according to the process by Brinkmann and Kvale [31]. As the project partners belong to organisations of different character and background, the interview script was intentionally broad. This to allow the interviewees to freely decide which aspects of the organisation they reside in were the most important.

One of the HUBCAP research institutes did not participate. Fifteen employees from the other project partners, covering one or several of the activities sought, were interviewed individually across two months. Informed consent was ensured, and permission to record the interviews acquired. During the initial interviews the two interviewers both participated to ensure a common understanding of the interview script. Later, in the interest of time, each interviewer conducted interviews separately.

2) Data Analysis: The interviews were transcribed and coded separately by the two interviewers. These aimed to acquire a common understanding of the interviews by discussing them in monthly meetings across five months. One of the interviewers then chose the examples that are presented in Section IV.

These examples were discussed among the authors to ensure a common and valid interpretation of the findings.

IV. Results and Analysis

This section presents the relevant findings from the questionnaire and interviews. The former is presented as summaries, which will be discussed in the synthesis. The latter is presented as *representative* quotes interspersed with the authors' analysis of the interviewees' responses. Clarifications by the authors are provided within square brackets.

A. Questionnaire

The results from the questionnaire are presented in four tables. Table I presents the support interest of the SMEs in regard to application domains they already do business in. Table II refers to application domains the SMEs do not, but want to, do business in. Table III presents the support interests of the SMEs in regard to scientific disciplines their engineers are experts in. Table IV refers to scientific disciplines that are of interest but in which the SMEs lack experts.

To support the readers' understanding of the analysis these results are also visualized in Figure 1 through Figure 6. Each figure visualizes the average percentages from combining the tables referring to application domains (Table I and Table II) or the tables referring to scientific disciplines (Table III and Table IV), with one of the associated categories highlighted in white.

B. Interviews

Naturally, organisations in academia will want their second- and third-cycle students to be possible to employ (also) externally. Interactions with industry to facility this transfer for second-cycle students are increasingly important. This involves an increase in industrial placements [19], but also a virtuous cycle of academia and industry interactions for the benefit of second-cycle students.

> *Example 1:* When its possible, we can send a [second-cycle] student ... that start collaborating with the company. Sometimes involved in a research project as a student and then graduate with a thesis on the topic which we are investigating with the company, and then the students remain there. So it's not just technology transfer through the fact that we explain something, but it's because we share the people.
>
> *Example 2:* You have to ensure that those people are influencing the training that you offer. So they have to be engaged in teaching. And that means they have to be influencing the content of the curriculum. And then in terms of business interaction, we put in place a lot of mechanisms for businesses to access our students ... ideally, we want about a third of our students to be out, taking an industry placement as part of their degree ... But in order for that to happen, we have to provide opportunities for businesses to come and meet our students. So businesses will set the challenge problems that students work on as part of their degree program ... They'll come in and help our students to develop skills like how to perform in a job interview ... We, you know, put our students doing mock interviews ... And, of course, those businesses are talent spotting. ... They come in and talk about what it's like to work in their profession and so forth ... That means they take our graduates and that is what completes the cycle.

Even firms that have little knowledge in regard to research focus their interactions with research roles on research activities. This makes the interactions regarding and involving third-cycle students different. Most importantly, firms might then not take on the role of (best practice) expert, but rather seek (state-of-the-art) knowledge that the students have elicited as researchers. Third-cycle students can thus end up interacting more with management roles in industry.

TABLE I
INTEREST IN SUPPORT FROM HUBCAP IN STRONG APPLICATION DOMAINS (PERCENTAGES)

	1 (No interest)	2	3	4	5	6	7 (High interest)	Response Rate
Identifying and approaching other funding sources	0	1,18	1,18	4,12	11,76	11,76	70	73
Accessing specialist, technical consultancy	4,71	5,88	9,41	10,59	17,06	18,82	33,53	73
Business development	0	0,59	3,55	6,51	13,61	20,12	55,62	72
Learning opportunities (courses, workshops, etc.)	2,96	5,92	10,65	11,83	26,04	18,34	24,26	72
Networking with other companies	0	1,18	4,73	7,1	13,02	24,26	49,7	72

TABLE II
INTEREST IN SUPPORT FROM HUBCAP IN WEAK APPLICATION DOMAINS (PERCENTAGES)

	1 (No interest)	2	3	4	5	6	7 (High interest)	Response Rate
Identifying and approaching other funding sources	1,26	1,26	2,52	6,92	8,81	15,72	63,52	68
Accessing specialist, technical consultancy	4,4	3,14	8,18	11,95	18,87	19,5	33,96	68
Business development	1,88	1,26	1,26	7,55	11,32	21,38	55,35	68
Learning opportunities (courses, workshops, etc.)	3,75	5,63	11,25	13,13	20,61	18,75	26,86	68
Networking with other companies	0	0,63	3,77	8,18	12,59	25,16	49,69	68

TABLE III
INTEREST IN SUPPORT FROM HUBCAP IN STRONG SCIENTIFIC SKILLS (PERCENTAGES)

	1 (No interest)	2	3	4	5	6	7 (High interest)	Response Rate
Recruitment of faculty or students	8,43	7,23	9,04	10,24	16,27	18,67	30,12	71
Accessing knowledge to solve problems you currently face	3,57	5,36	8,93	11,9	12,5	26,79	30,95	72
Access to knowledge on new, novel technology	0,6	2,99	2,99	8,38	11,98	23,95	49,1	71
Identifying and joining research projects	0,6	1,79	2,98	7,74	8,93	17,26	60,71	72

TABLE IV
INTEREST IN SUPPORT FROM HUBCAP IN WEAK SCIENTIFIC SKILLS (PERCENTAGES)

	1 (No interest)	2	3	4	5	6	7 (High interest)	Response Rate
Recruitment of faculty or students	17,76	6,54	4,67	9,35	17,76	14,95	28,97	46
Accessing knowledge to solve problems you currently face	10,28	2,8	5,61	12,15	9,35	19,63	40,19	46
Access to knowledge on new, novel technology	10,28	0,93	3,75	9,35	14,02	14,02	47,66	46
Identifying and joining research projects	9,35	0,93	4,67	8,41	11,21	16,83	48,6	46

Example 3: Its based on the the expertise of the company in research projects ... it happens sometimes that we are approached from an industrial company, even big companies, and since they have never worked in this type of, of research activities, they think that we are somehow some kind of wizard or magicians, which can do everything for them. This is a very big issue. In my opinion, at least, because in particular, in the first month of cooperation of a business relation, they do not know what they want ... or they want something which they don't need.

Example 4: When they are industrial partners, we [as researchers] usually ... [interact] with the CEO or with the digital manager ... and with them depending on the project, the production manager or the maintenance manager.

Furthermore, the need to align the interests of academia and industry becomes more acute in these interactions. Especially as the cost benefits might be much less than when utilizing second-cycle students.

Example 5: My primary aim is to find opportunities to develop applications for collaborative research. So that would be either funded directly by the company. So the company pays university to engage on on a piece of work, or where we would apply jointly to government sources. Or thirdly, where we would, as an academic body, apply to funding councils and bring companies as company collaborators ... So consultancy as a service to the company in return for payment, we're less inclined to want to work in that way. And as most universities are concerned about advancing knowledge and developing new knowledge, we're much more likely to engage with them if that is going to be the case ... [it is] kind of two sides to a project coming together ... One is the company with something they want to do. And the second side is an academic who is interested in what that company is looking to do because it advances their knowledge, gives them an opportunity to learn something new ... [Consultancy] is less likely to get the interest, the real interest of the academics. Because in general, they're not short of funds, what they are short of [are] new research angles.

Example 6: So our starting point has to be [high cost] Euros, and then we allowed in a small margin, maybe 20%. So we might be starting off on [high cost] Euros a day for a relatively junior member of staff.

However, when these interactions do lead to collaboration, they are often started by previous students coming back to get support with solving problems that are beyond best practice. For third-cycle students this can also be seen as a virtuous cycle, but in which industrial challenges drive the research agenda of academia.

Example 7: So, the [second-cycle] student complete his thesis and then go working for a company, which could be small and could not have the skill in a particular technology or a particular methodology ... he is younger there, he is proactive and he sees a problem which maybe was unseen to the management. But, since he is a junior figure, he has not the competency to find a solution ... and so the first thing he does is to take his phone and call for [the] professor [supervising his thesis].

Example 8: This virtuous cycle is part of that ... we see the training of PhDs, as being for industry every bit as much as academia. The vast majority of our PhDs will not be academics. I mean, in the [Country] ... maybe 5% of PhDs go on to become academics. The vast majority will go into industry. Those folks go into businesses tackling some of the most demanding, challenging, technical problems that those businesses are dealing with. They will also identify the problems that cannot be solved now, and those become for us research challenges ... And that drives our research agenda. And those researchers who work on that research agenda ... they develop and deliver the training to the next generation of PhDs, and that completes the cycle.

Still, these interactions are often more difficult for SMEs than for other firms. SMEs often lack resources and have a hard time understanding the interests and limitations of academia. However, an exception in regard to the latter is SMEs started by former faculty or third-cycle students. These often understand both academia in general, and the interests of their old colleagues in particular.

Example 9: We have this situation in which SMEs sometimes tend to see universities [as] far from their business.

Example 10: Many of those who approach us ... are not companies who have engaged with, or worked through, a university environment before, so their expectations need to be managed. So often they think it's going to be very cheap to work with the university because they've already paid their taxes. So why would the university want to charge again? They will often think that staff are sitting waiting for the call, they have not really got very much on ... because they maybe associate university staff with for example secondary school teachers or something of that kind.

Example 11: When you know someone from a company they tell you from the beginning "Ok, this is not a project which we are interested in" ... you gain a lot of time. Because, otherwise, you have to go through a long procedure ... to be approved by different levels ... at least in big companies. For SMEs, it is easiest because [I and] my former colleagues or my former students ... in five minutes, we go together or not. But, unfortunately, SMEs do not have enough resources.

V. Discussion

Established, knowledge-intensive SMEs require recruits with an understanding of the state-of-the-art, but with an additional focus on products and customers [26]. This might explain the relatively low interest in technical consultancy and recruitment of academics reflected in Table I through Table IV (see Figure 1 and Figure 2). This implies that supporting the important job growth in SMEs [7] requires new foci for the skill development of third-cycle students. Unfortunately, teaching third-cycle students the informal skills required to work closer to products and customers will encounter similar challenges as for second-cycle students: the academic context might be suited for teaching formal professional skills, but informal skills rather require informal interactions with peers [32]. Enabling such interactions is typically difficult without learning environments with more socio-technical complexity and less emphasis on academic practice than higher education institutions can provide [33], [34].

Be that as it may, our study suggests that there are at least two important roles at knowledge-intensive SMEs for which academia could enhance skill development. Furthermore, public-private innovation ecosystems could provide suitable learning environments for this skill development regarding third-cycle students. In this section we discuss these two roles, and the related implications for academia as public-private innovation ecosystems increase in importance.

A. The Academic Boundary Spanner

One important role that can be filled by PhDs in SMEs is that of a boundary spanner to academia. As indicated in Section IV, personal connections to research groups and an understanding of academia can be used to enable collaboration with a minimum of conflicts. In fact, this is used by certain SMEs to get access to informal training on the latest research findings [35], thereby avoiding the high costs associated with formal training. This might explain the relatively low interest in formal access to learning opportunities reflected in Table I and Table II (see Figure 3). A PhD's ability to enable the virtuous cycles mentioned in Section IV can also be important. Engaging with the virtuous cycle regarding second-cycle students can both be appreciated by old colleagues and enable SMEs to hunt for talents aligned with growth needs. In fact, if this is based on a strong mutual trust it might enable second-cycle students to learn informal skills [17] and transition more easily to industry [20]. However, given the strong emphasis

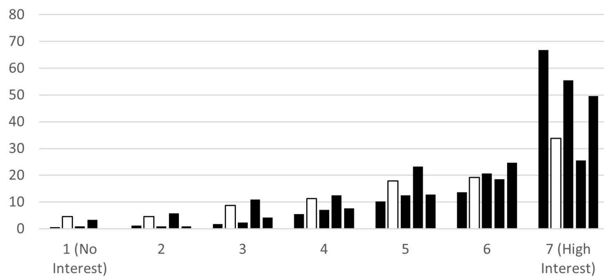

Fig. 1. Average percentages from the combination of Table I and Table II, with technical consultancy highlighted in white.

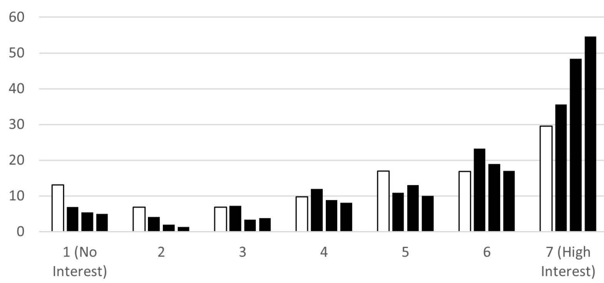

Fig. 2. Average percentages from the combination of Table III and Table IV, with recruitment of faculty or students highlighted in white.

on knowledge generation by academia, it is more difficult to grow these (strong) relationships without also engaging in research-related activities. Indeed, as indicated by Section IV, academia typically requires a stronger alignment than technical consultancy to maintain a relationship. To the benefits of industry in regard to accessing and directing research already mentioned [16], one can thus also add the social capital gained by engaging with the virtuous cycle involving third-cycle students.

The strong emphasis on support in identifying and engaging with funding sources and research project reflected in the interviews, and Table I through Table IV (see Figure 4 and Figure 5), then represents an opportunity. Engaging with academia in setting up joint research can be more than only a way of accessing funds, but also secure employees and knowledge for future growth. However, a transfer to industry based on this opportunity will require skills in securing funding and initiating research studies, which are skills typically not learnt until later in an academic career.

In-depth knowledge in particular research areas is then only a prerequisite. Project management skills are also required, especially as related to international and inter-organisational collaboration. Firstly, because this role will depend on the ability to appropriately frame the utility of research. Different funding bodies have their own aims and purposes, which must be related to a research proposal for it to be funded. Furthermore, the possibility to achieve a high impact for all relevant stakeholders must be conveyed appropriately. Secondly, because project management skills confers the ability to identify a balance between having feasible and ambitious research aims. In other words, the ability to see the effort, risk and resources involved in pursuing specific outcomes, and weigh this against the gain this would represent for both industry and academia.

B. The Industrial Boundary Spanner

Another important role that this study suggests that PhDs in SMEs can fill is that of the boundary spanner to other firms. Both Table I and Table II (see Figure 6) show a strong interest by the SMEs to network with other firms. Indeed, networking in loosely coupled networks with dominant nodes that favour open knowledge sharing will often result in knowledge spillover [36]. In fact, this can be an explicit goal of knowledge and innovation networks led by academia [37]. The result is often new products born from the recombination of technologies from different contexts. However, actually enabling firms to systematically benefit from networking is challenging as employees from different firms often have different expertise and backgrounds. A basic task for a boundary spanner is then to enable cooperation by repackaging external knowledge to make it understandable inside a firm [38]. This requires an expert with both a breadth and depth to his intellectual capital [25], [22]. A PhD might thus be a prerequisite to enable a fruitful sharing of the type of advanced knowledge found in public-private innovation ecosystems and knowledge-intensive SMEs.

Furthermore, to establish networks and get access to relevant knowledge, a boundary spanner in a public-private context might also require time, empowerment, a certain type of personality, and a certain skill set [39]. As for the academic boundary spanner role, project management skills as related to inter-organisational collaboration are thus also required for this role. However, rather than skills related to planning, this

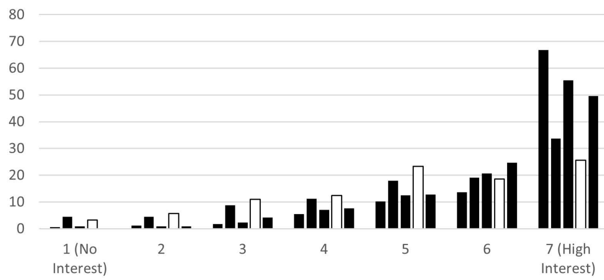

Fig. 3. Average percentages from the combination of Table I and Table II, with learning opportunities highlighted in white.

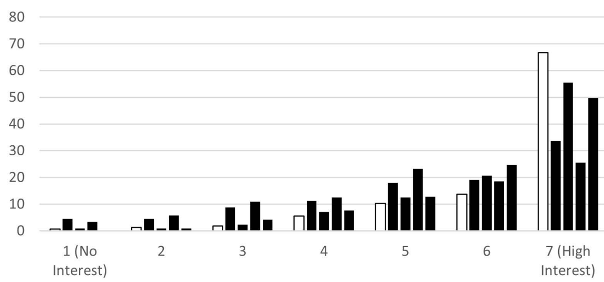

Fig. 4. Average percentages from the combination of Table I and Table II, with engaging with funding sources highlighted in white.

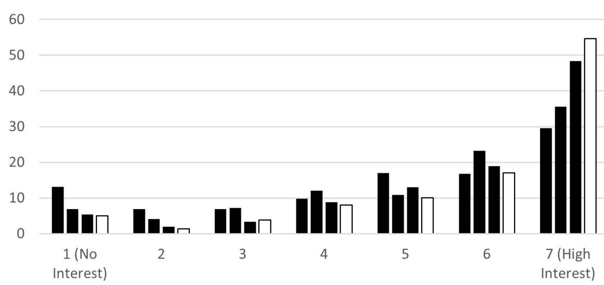

Fig. 5. Average percentages from the combination of Table III and Table IV, with engaging in research projects highlighted in white.

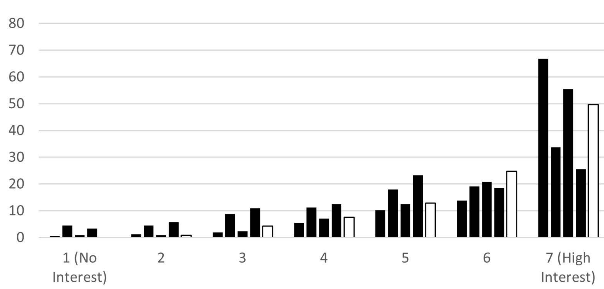

Fig. 6. Average percentages from the combination of Table I and Table II, with networking with other firms highlighted in white.

type of industrial boundary spanner needs project management skills related to e.g., bargaining and negotiation. In other words, rather than skill in explaining goals to, and matching goals to those of, a funding organisation, this role requires people with the ability to actively influence others to align with the goals of their SMEs.

C. *Implications for Academia*

In addition to the identified need for additional skill and knowledge development in third-cycle education, this study brings about implications for the design and use of university support structures. Many universities, and in particular those with a strong focus on the applied sciences, have in the last decades focused increasingly on developing support structures for third-mission activities. This includes e.g., innovation incubators, technology transfer offices, and entrepreneurial training of both students and faculty. Earlier studies have revealed that these structures are useful for the commercialization of engineering-focused research, but typically have a narrow focus on patents and generation of start-up companies [40]. Arguably, this narrow focus, which tends to be predominant in both research on academic commercialization and within university management, needs to be extended to a more comprehensive view on value creation from academic research. The results from this study thus highlights two associated aspects of university support structures that need further attention. Arguably, these can be directly linked to public-private innovation ecosystems as learning environments for third-cycle students seeking to transfer to early careers in knowledge-intensive SMEs.

Firstly, the overly narrow view on value creation in terms of intellectual capital should be complemented with a more explicit focus on human and social capital. Innovation does not only require technical resources to be realized, but also the right circumstances. Successful innovation thus often relies on networks of people that interchange knowledge and, often more crucially, ensure organisational learning. Arguably, university support structures need to reach out beyond their own, immediate concerns and engage with such networks. Of particular interest is then the non-transient character of inter-organisational projects involving SMEs [41]. A third-cycle student who has the opportunity to engage with inter-organisational, industrial projects through the management connections indicated by Section IV should also have opportunities to engage with long-term networks working on predominantly routine tasks using traditional project management tools. Informal interactions with these professionals will provide skill training on inter-organisational project management that is otherwise difficult to access.

Secondly, this narrow focus on commercialization is also nested in an overly linear view, in which innovations almost by necessity develop from academic research. The implicit focus thus becomes innovations that can easily be packaged as either explicit or tradeable knowledge. With such a focus there is a clear risk that innovation activities focusing on more complex systems innovation, in which multiple stakeholders jointly and interactively contribute to the same overall innovation goal, are overlooked. Given the overall development towards more complex, multi-technological firms and firm collaborations, this type of innovation will become increasingly important. Forward-looking universities will thus need to develop an associated, new set of support structures and activities. These support structures could most likely not remain as generic as incubators and technology transfer offices due to the technological and relational complexity characterizing e.g., public-private innovation ecosystems. Consequently, the support resources will have to be more distributed and require integration roles populated by individuals or teams with a combination of both in-depth engineering knowledge and innovation skills. In other words, support resources capable of matching the boundary spanning roles that third-cycle students could transition to given the right support for skill development. Arguably, such roles will be well placed to introduce third-cycle students to the networks discussed in the previous paragraph.

VI. Conclusion

Third-cycle engineering students that pursue an early career in SMEs that take part in public-private innovation ecosystems will require a different skill set than required by those that turn to academia, large firms or even entrepreneurship.

This study identified two roles that would match both the interests of SMEs in this context and the in-depth knowledge of the state-of-the-art possessed by an early career PhD. The first is the role of the academic boundary spanner, who works in close collaboration with academia to secure additional funding, personnel and knowledge for future growth. This role will require a PhD who has also learnt project management skills related to the planning of complex collaboration. The second is the role of the industrial boundary spanner, who works with other SMEs to broker knowledge for value creation. This role will require a PhD who has also learnt project management skills related to complex collaboration, but in regard to bargaining and negotiation.

These skills are typically important to a PhD that pursues an academic career, but not until later in that career. Therefore, third-cycle education typically does not emphasise these two skill sets. To support the third mission also in regard to knowledge-intensive SMEs this should be reconsidered. Simultaneously, this implies the need to evolve university support structures for innovation. On the one hand, by increasing their focus on human and social capital; on the other hand, by creating more distributed innovation roles that combine both in-depth engineering knowledge and innovation skills. The former should create innovation roles in universities that reach out further into the industrial networks that bring about innovation. The latter should provide an established way of introducing third-cycle students to these industrial networks. Together, these changes should give third-cycle students opportunities to access informal training necessary for the two identified boundary spanning roles.

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