Interagency, Collective Creativity, and Academic Knowledge Practices

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Abstract. The purpose of the present article is to examine collective creativity regarding academic research from the activity-theoretical and socio-cultural perspectives. The authors argue that collective creativity regarding academic research relies on collaboratively cultivated academic knowledge practices, appropriation of which provides an access to cognitive-cultural operating systems of academic research (i.e., a disciplinary-specific activity system). Pursuit of doctoral studies in a research community appears to elicit the development of object-oriented interagency needed for systematic pursuit of coordinated research efforts. The growth of participants' capabilities of independent research appears to take place through improvisational pursuit of inquiries and associated co-authored articles involving gradually stronger creative personal contribution. The collective intelligence of academic research is embedded in expansive or cultural learning of research communities and networks that supercharge the subsequent doctoral-student cohorts' knowledge practices in a way that elicits academic excellence.

Keywords: activity theory, collective creativity, collective model of doctoral education, expansive learning, individual model of doctoral education, interagency, knowledge practices, cognitive-cultural operating system.

Introduction

The purpose of the present "working paper" is to examine collective creativity involved in academic research, especially in groups involving doctoral students. The present paper has been written to elaborate a socio-cultural and activity-theoretical view of the knowledge-creation processes involved in doctoral education (see Beauchamp, Jazvec-Martek, & McAlpine, 2009 for a parallel effort). To a great extent, this paper is, however, still work in progress; we did not have adequate time for collaboratively reflecting on these issues, and had to prematurely end the inquiry. The present investigation has been carried out at the two complementary levels, i.e., at the level of reflecting on our own research practices and in terms of analyzing academic research practices of three highly regarded external research communities. The present investigators are, on the one hand, research practitioners who are, to a great extent, analyzing and reflecting on their own academic research practices across the following pages. Accordingly, academic research is an essential aspect of "what we do" in our everyday activity as educational researchers. The initial impetus of starting to study academic knowledge practices emerged from encountering puzzling observations and going through extremely difficult personal and social transformations (Engeström, 1999a) concerning our own academic practices.

On the other hand, the present investigators have over some years investigated academic knowledge practices of several highly regarded academic research groups. We are in the process of analyzing data rather unique in scope in the field of studies of doctoral education; they involve a) self-report questionnaire responses of 669 doctoral students, 2) interviews of 53 doctoral students working in three highly regarded research communities, 3) ego-centric

network and doctoral process interviews of 20 students (20 more interviews planned), 4) interviews of 14 supervisors representing three domains of knowledge, 5) some videotaped supervisor-doctoral student meetings and research meetings. In addition, we have interviewed 24 national and international research leaders' of collaborative research communities. These investigations are about to be expanded by social network analyses and analyses of co-authorship networks.

The main concern of the present paper is to develop an account of academic knowledge creation involved in doctoral education that assists in understanding the collective embeddedness of academic excellence in shared knowledge practices, appropriation of which allows investigators to account for dynamic development of unique and exceptional personal capabilities as well; for achievement of academic excellence by ordinary investigators participating in collectively cultivated extra-ordinary knowledge practices.

Dilemmas of individual and collective doctoral education

Doctoral training has traditionally been described as a process in which an inexperienced doctoral student is thrown into a river and the supervisors determine whether she or he learns to swim; if the agent survives, he or she is assumed to be capable of academic work. It is an extremely challenging double-bind situation (Bateson, 1972; Engeström, 1987): the doctoral student has to jump into the unknown to create new knowledge and competence required for the doctorate by relying on competencies that have not yet been developed. Everyone, even members of collaborative research communities, experiences being alone in such a situation (Delamont et al, 2000). Every doctoral student has to work at the very edge of his or her competence; research data reveal that the process is very frustrating and anxiety-laden to the participants (Traweek, 1988; Delamont et al., 2000).

Most doctoral students consider interrupting the process, and their attrition is a major problem across the world with many psychological, social, and societal costs (Gardner, 2007; Golde, 2000; 2005; Smallwood, 2004). Many investigators report that 30-50, even 70% of doctoral students interrupt their post-graduate studies, in many cases, permanently discontinuing. This takes place for many reasons, including experienced lack of support, degree requirements that appear ambiguous (such as unclear disciplinary norms concerning acceptable doctoral thesis), slow progress, financial difficulties, and so on. Doctoral students represent a very selected population, academically the "best of the best" representatives of their generation. Investigations indicate, further, that formal competencies of those who interrupt do not significantly diverge from those of students who succeed in completion of their studies (Smallwood, 2004). In spite of the strategic importance of academic research in the present day innovation-driven society, many aspects of academic knowledge practices are poorly understood and remain as a black box. Investigators cannot truly explain why so many apparently talented students fail and how some students without exceptional skills and competencies succeed in spite of encountering numerous obstacles and difficulties. Implicitly, if not explicitly both professors and doctoral students themselves appear to assume that some sort of mysterious personal talent plays a crucial role, how else it could one account for both the successes and the failures.

It appears to the present investigators that one of the weaknesses of the above refereed research on doctoral education has been the attempts to examine the doctoral process in terms of individual learning and knowledge-acquisition. This appears as a serious weakness when one considers that a major part of academic research in Finland, Europe and across the world is conducted through doctoral education. The present investigators' research on doctoral education capitalizes on their long-standing efforts in understanding knowledge-creating learning (Paavola, Lipponen, & Hakkarainen, 2004; Hakkarainen, Palonen, Paavola, & Lehtinen,

2004). While analyzing processes and mechanisms of technology-enhanced learning, they have become aware that learning of students representing various levels of education could neither be described as a process of acquiring knowledge provided by teachers or textbook (the acquisition metaphor of learning) nor as a process of growing up and socializing to an already existing community (the participation metaphor of learning, see Lave & Wenger, 1991; Sfard, 1998). Specifically, the process involved genuine collaborative advancement of knowledge and transformation of prevailing practices. Rather than involving mere individual and mental processes (subjective within mind monologue) or social interaction (intersubjective dialogue between minds), knowledge-creation processes embedded in collaborative learning technologies were mediated by various epistemic artifacts created by the participants. Such learning processes appeared to be oriented toward collaborative advancement and development of epistemic objects (Knorr-Cetina, 1999; Rheinberger, 1997; Miettinen & Virkkunen, 2005). In order to account for such processes, we started to talk about trialogical learning (Paavola & Hakkarainen, & Sintonen, 2006), i.e., learning involving trialogue between individuals, communities and the shared objects being jointly developed. One of the reasons for studying doctoral education has been our desire to understand better the collaborative dynamics of knowledge creation in which collectively cultivated knowledge practices (Hakkarainen, 2009; Hakkarainen, Lallimo, Toikka, & White, in press)., i.e., shared practices of working creatively with knowledge, play a crucial role.

The individual and collective models of doctoral education may be distinguished from one another (Becher & Trowler, 2001; Delamont et al., 2000; Turner, Miller, & Mitchell-Kernan, 2002; Pilbeam & Denyer, 2009). *The individual model* is typical of humanities and social sciences involving doctoral students pursuing monographs based on supervised individual research projects; such supervisor-student dyads do not usually have a shared object of inquiry; the supervisor is rather assisting the student to attain his or her personal research objectives. It appears that, in many cases, a heroic supervisor as well as a heroic doctoral student is needed to make the process succeed. The former may be willing to sacrifice his or her own career for supervising students pursuing their own lines of inquiry whereas the latter is ready to make exceptional efforts to re-construct productive academic knowledge practices without sufficient modeling and guidance beyond weak networking linkages provided by occasional research meetings. *The collective model* is typical of natural sciences; it focuses on creating co-authored articles within research communities; the collective model involves research on collectively shared problems embedded on the supervisor's networks of research projects. Many investigators appear to take the distinction between the collective and lone-scholar model as given; it is assumed somehow to represent differences in the very nature of knowledge creation characteristic of, on the one hand, natural sciences and, on the other hand, humanities and social sciences (Becher & Trowler, 2001). Here investigators refer to the epistemological differences in knowledge (natural sciences having agreed foundations whereas those are contested in humanities/social sciences), methodological differences (natural sciences relying on experimental system requiring cooperation of multiple investigators and research communities whereas social scientists can manage do research by relying on their personal resources), and the nature of published epistemic artifacts (monographs correspond requirements of writing-intensive humanities whereas articles are suitable to decomposable problems of sciences).

Insufficient attention has, however, invested in historical examination of knowledge practices across disciplines; accordingly, many investigators assume that the present divide represents stable and ahistorical differences between natural sciences and humanities/social sciences. This does not, however, appear to be an adequate position. Natural sciences relied on the lone-scholar model in the beginning of this century and the collectivization of academic re-

search is a relatively recent phenomenon (Merton, 1973; Thagard, 1997). Moreover, it is not restricted to natural sciences; across many other sciences there is a clear trend of increasing number of co-authored publications based on collective work of research communities and networks (for an analysis of evolving co-authoring practices in biology and economy, see Laband & Tollison, 2000). Psychology is a social science in which the trend has been very strong for younger generations of researchers to be trained within the collective model and to systematically pursue co-authored articles. This disciplinary culture, however, went through a very strong transformation over the last three decades. Many of the present investigators own professors working at the Department of Psychology, University of Helsinki relied on the solo-inquirer model in respect of not being able to pursue co-authored international publications (or provided corresponding competitive scientific funding). The situation has completely transformed for younger generations of researchers being trained through the collective model. In Finland, a well-established practice in social sciences is to pursue article theses consisting of four internationally refereed journal articles. Across the last decade, this approach has increasingly been adopted also in social sciences as well as in education. The proportion of co-authored journal articles published by Finnish social scientists has increased from 38% to 56% between 1998 and 2004; across all publication formats from 30% to 46% (Puuska & Miettinen, 2008). The present investigators have taken the collective model to the educational sciences and there are numerous other groups who are doing the same, so that it is becoming a dominating cutting-edge orientation.

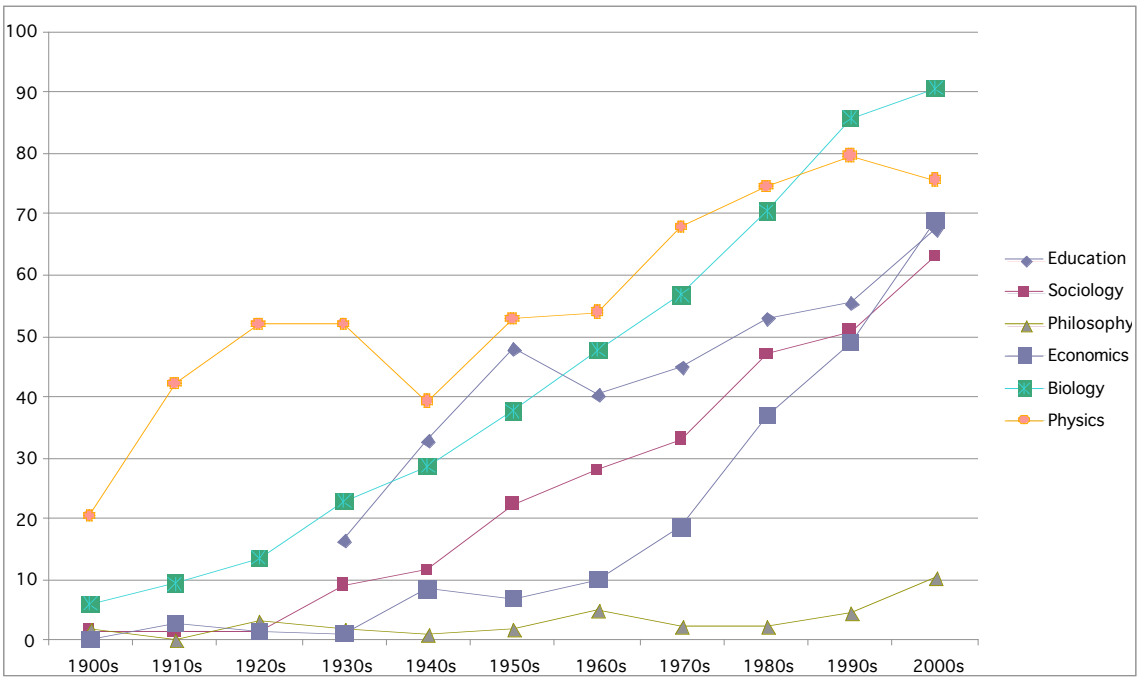

Figure 1. Collectivization of academic research in terms of increasing proportion of co-authored articles in high-impact journals (the data relies on 36000 journal articles published in the most highly regarded journals across disciplines, I would like to thank Juho Makkonen for collecting the data).

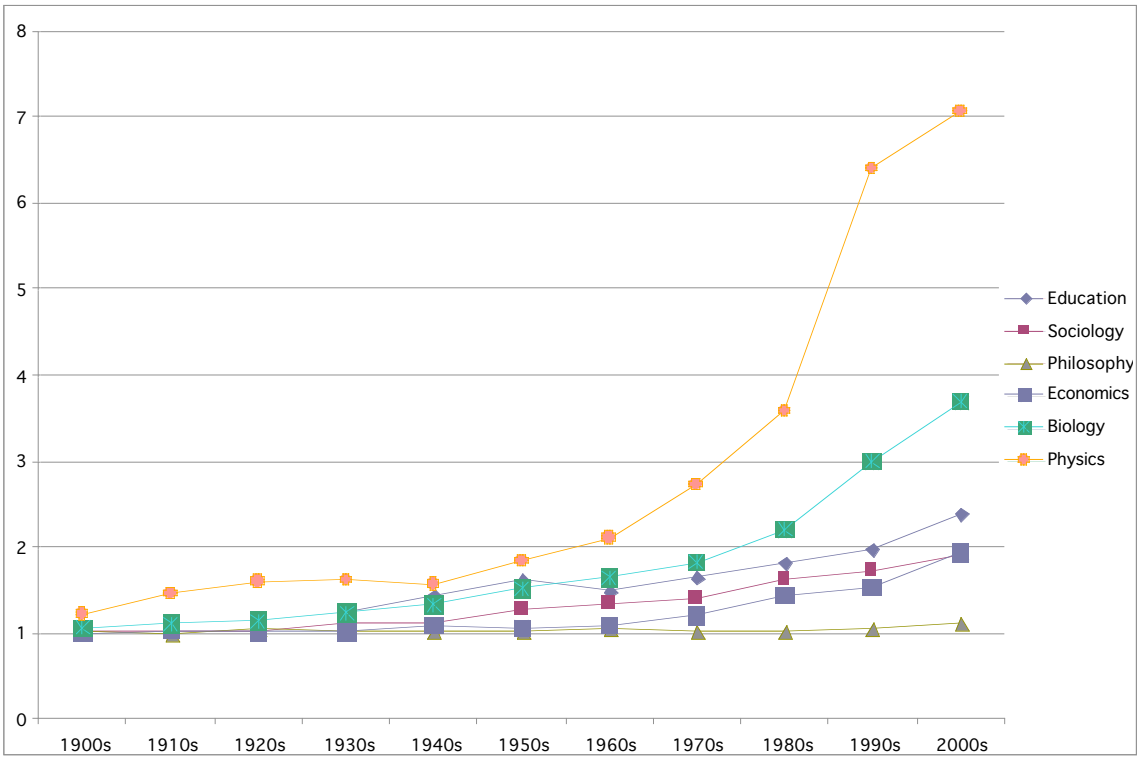

Figure 2. Collectivization of academic research in terms of increased number of authors in articles appearing in high-impact journal across disciplines (I would like to thank Juho Makkonen for collecting the data).

Although many aspects of doctoral education might be looked into, including completion of the course work, adequacy of supervision, and so on, it appears that the expansion of investigations toward structures, processes, and mechanisms of socializing doctoral students to academic knowledge creation is likely to play a key role in understanding and successfully developing of doctoral education.

The challenge of transforming knowledge practices

One of the motivations of this study is the present investigator's and his colleagues experiences of creating collaborative research communities in education and psychology; we aimed to expand the collaborative model of doctoral education to the social sciences. Parallel personal and collective transformations that Hakkarainen and his colleagues went through across a decade of research efforts from 1995 to 2005, appear to be relevant from the perspective of understanding collective creativity regarding academic research. As a doctoral student Hakkarainen established with some colleagues Centre for Research of Networked Learning and Knowledge Building (www.helsinki.fi/science/networkedlearning) that was completely funded by external research projects with provincial school administration and the European community. Across the decade, the centre grew from 2-3 investigators' group to a relatively large community involving 15 full-time doctoral students and postdocs. Initially, the group was constrained by requirement of external project funding; the investigators were expected to produce traditional thick research reports (without peer review whatsoever), which allowed funding agencies to indicate their productivity and existence of highly valued academic ties. Pursuit of such epistemic artifacts was in accordance with monograph theses that Hakkarainen and some other senior researchers had been guided to produce at graduate and postgraduate levels.

Figure 1 indicates how Hakkarainen's research centre transformed toward a unit focused on publishing scientific journal articles across a ten-year (1995-2005) span. During the first two years there were no publications. During *Stage I* ("cemetery publications") the object of research community's activity was to produce national and European level research reports. Being labor-intensive to produce, without a peer review, such research reports did not, however, contribute to the academic record. In a few years, the publications produced tended to disappear to the "cemeteries of knowledge" to the extent that it is very difficult to get access even one of them. In *Stage II*, the object of activity changed to internationally refereed conference papers and book chapters so as to answer external performance requirements. Their scientific activities took place under extreme time pressure that limited available degrees of freedom. Knowledge practices representing the second stage emerged as a kind of compromise: creating full papers for conferences became attainable while still continuing to produce project reports. In terms of research design and methods, corresponding knowledge practices guided the participants to focus on more academically oriented investigations. Pursuit of these "who-you-know" publications did not involve peer review beyond a superficial level; people already familiar with each other's work were doing the peer review, and even one cycle of corrections was seldom required and appropriately confirmed by reviewers. Standards of peer review were not high in spite of the fact that many of the conferences in question accepted only 20 percent of submissions.

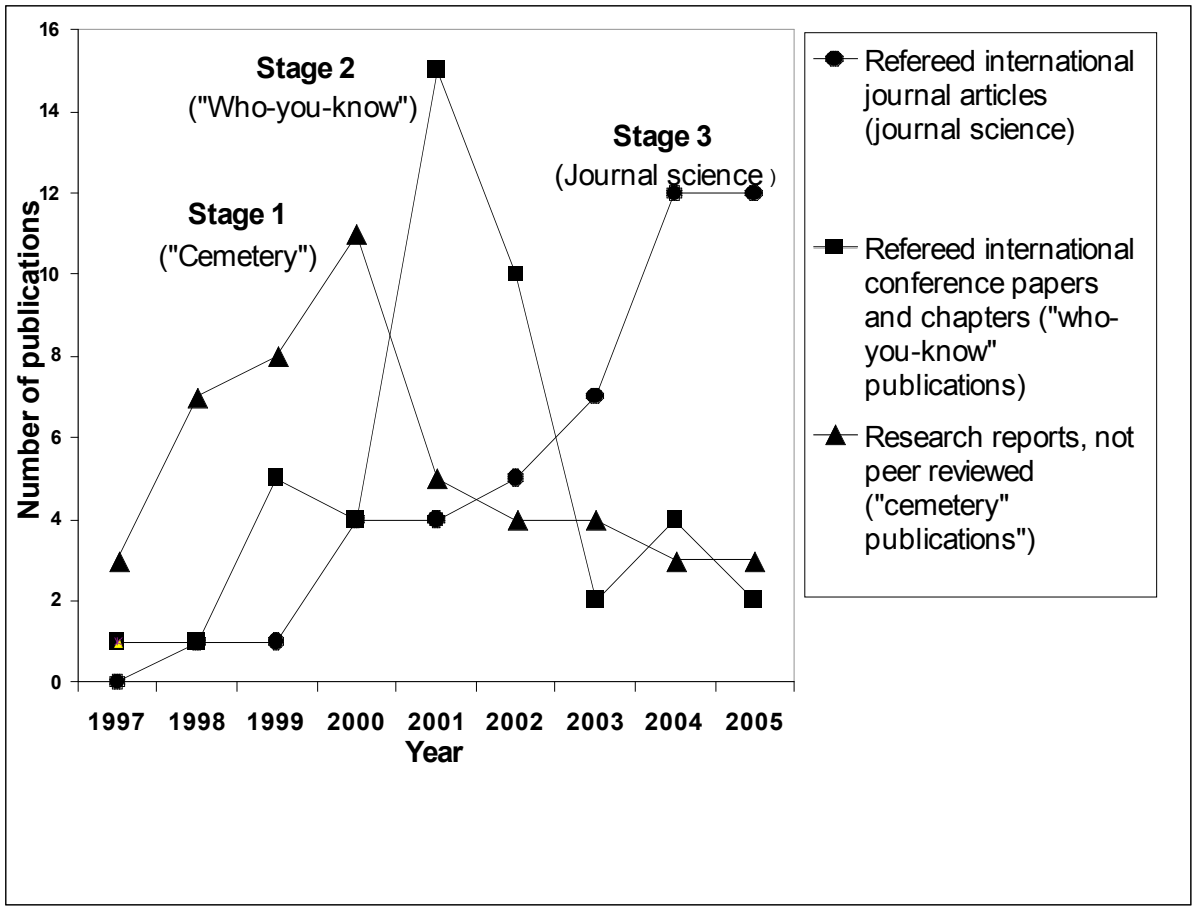

Figure 3. Transformation of publication-related knowledge practices at the Centre for Research on Networked Learning and Knowledge Building across a ten-year period

Toward the end of the period examined, there emerged knowledge practices systematically focused on producing scientific journal articles. Transition to *Stage III* took place when an external evaluation of the research leader's scientific competence in 2002 revealed that a

hundred conference papers and research reports were not considered as academic contributions at all by external evaluators. This pushed his research community to decide, collectively, to profoundly change its knowledge practices. Following the example of internationally oriented research groups, every full-time doctoral student was required to pursue an "article" thesis consisting of at least 4 internationally published refereed scientific journal articles. From the perspective of evolving knowledge practices, we instituted yearly departmental workshop in which every investigator had to report his or her scientific productivity. The participants represented heterogeneous knowledge practices, including those of a national centre of excellence; this, indeed, facilitated hybridization of knowledge practices, contributed to the transformation from Stage I toward Stage II and, further, to Stage III.

Appropriating more advanced knowledge practices allowed the research community to expand the object of its activity and achieve its collective zone of proximal development (Engeström, 1987). Engaging in journal science furthered obtaining "good" academic research money and required training of funding agencies (e.g., provincial departments of education, EC) to accept journal articles as deliverables. After initial problems, it was not difficult to convince funding agencies that pursuit of international journal articles would provide more valuable and durable scientific contribution than traditional research reports without peer review; the funding agencies needed, however, to be trained to acknowledge academic value of publications. The present investigators maintain that the transformation in question is a paradigmatic example of cultivation of collective creativity that cannot be reduced to individual participants' knowledge and competence. Pursuit of international refereed articles is more intelligent, with respect to advancement of science or of one's academic career, than production of other kinds of publications because the articles not only crystallize intelligence of the authors but also the expertise of an expanded network of investigators, including the reviewers (Hakkarainen, 2003b). Unlike research reports, articles published in a scientific journal are accessible to future generations of investigators; this allows capitalization of the cumulative advantages of academic research in respect of having feedback and reciprocal networking connections with external communities interested in one's inquiry.

The hypothesis of the present investigation is that learning to do international scientific publication requires sustained and parallel personal/collective transformations (expansive learning, Engeström, 1987; 1999a) involved in changing an activity system of traditional publication practices (Figure 5) to that of cutting-edge academic knowledge practices (Figure 4). Pursuit of research monographs (a research report, a monograph thesis) and journal articles are *two different types of activities*. Mastering the project research does not allow an investigator to pursue journal science. Many people experience the transition as insurmountable; it is difficult because it requires expansive learning for which human beings do not appear to have readily available cognitive mechanisms. It might be mentioned, briefly, that we have here used the term 'monographs', instead of 'reports.' In fact the latter is usually more accurate. Doctoral theses and project reports are typically not publishable as monographs. The emergence of publication-related knowledge practices requires transformation of social practices, and associated habitus, Bourdieu, 1980) in creating a novel activity system (Engeström, 1987). The theory of the 'activity system' is based on a few central points: the object-orientedness of human activity, mediation through cultural-historically developed tools of activity, and contradictions emerging between the elements of activity systems. Engeström (1987; 1999a) has expanded Vygotsky's (1978) model of mediated activity toward the collective level by relying on Leont'ev's (1976) analyses. This perspective focuses on examining reciprocal relations and inter-dependence between individual actions and collective activities. Collective activity has its own motive under which individual actions are subsumed and that they serve according to division of labor and communal rules guiding the activity. Doing new

things is difficult both for academic researchers and their communities, but necessary when practices embedded in the activity system are not sufficient for solving and conceptualizing contradictions arising within the system or in relation to its environment.

Figures 4 and 5 present, respectively, activity systems concerning traditional (monograph-related) and international publication practices. Publication practices appear to concern the overall object or motive of activity rather than theoretical or methodological competencies involved in scientific expertise as such. In the case of the present research community, the participants mastered many of basic research skills already in the beginning, but were not able to translate these skills adequately to genuine academic contributions. The *object* of the present investigators' practices of working with knowledge was compatible with pursuing traditional relatively thick monograph-like research-reports. The *subject* involved individual or co-authoring investigators; they pursued research reports by relying on *instruments* provided by personal productivity tools (text, graphical, and statistical processing). The activity relies on locally emerged informal *rules* and improvised *division of labor*. Beyond authors, the *community* involved other members of the research community as well as external stakeholders, such as representatives of funding agencies whose own productivity partially relied on the research reports produced. Interestingly, such practices involved, for instance, substantial formatting of documents by investigators themselves; when we changed publication practices, such habits of working with text had to be given up in conjunction with following disciplinary and journal-specific publication guidelines.

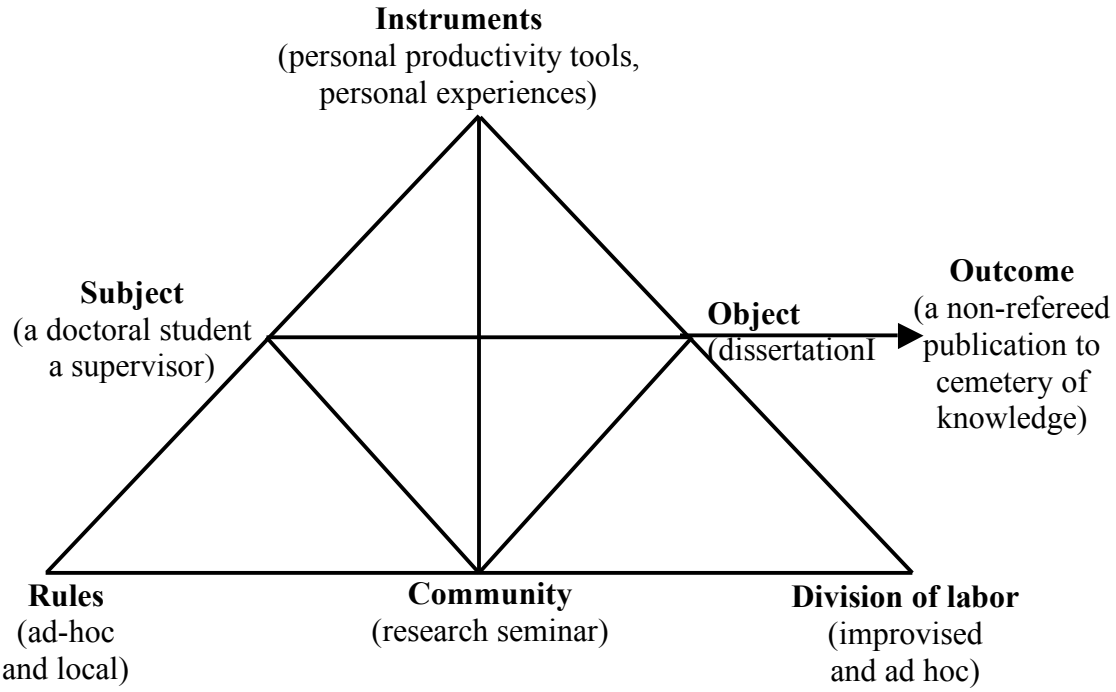

Figure 4. A rough outline of an activity system (Engeström, 1987) of traditional practices of monograph science.

As a consequence of appropriating and cultivating a publication culture in the international arena, investigators' activity system changes (Figure 5). In order to produce publishable journal articles, investigators had to learn to work from the start towards creation of relatively short documents. The *object* is not, anymore, simply to meet the goals of a particular research project, but an expanded object of creating a journal article that contributes, in a recognized way to filling in a gap in scientific cultural knowledge (compare Engeström, Puonti, & Seppänen, 2003; Engeström, 2004). The *instruments* involve, among other things, the journal's

submission system that is likely to be virtual in nature. Further, the *rules* of editing are subject to journal-specific editorial requirements, and within APA or some other style guidelines. So, as already stated, our formatting practices changed: Final formatting was left to the journal's editorial office. The *community* of publishing changed in terms of researchers incorporating reviewers' contributions with their own. The *division of labor* transforms through distributing efforts among a whole network of actors, when starting to pursue publication of international journal articles.

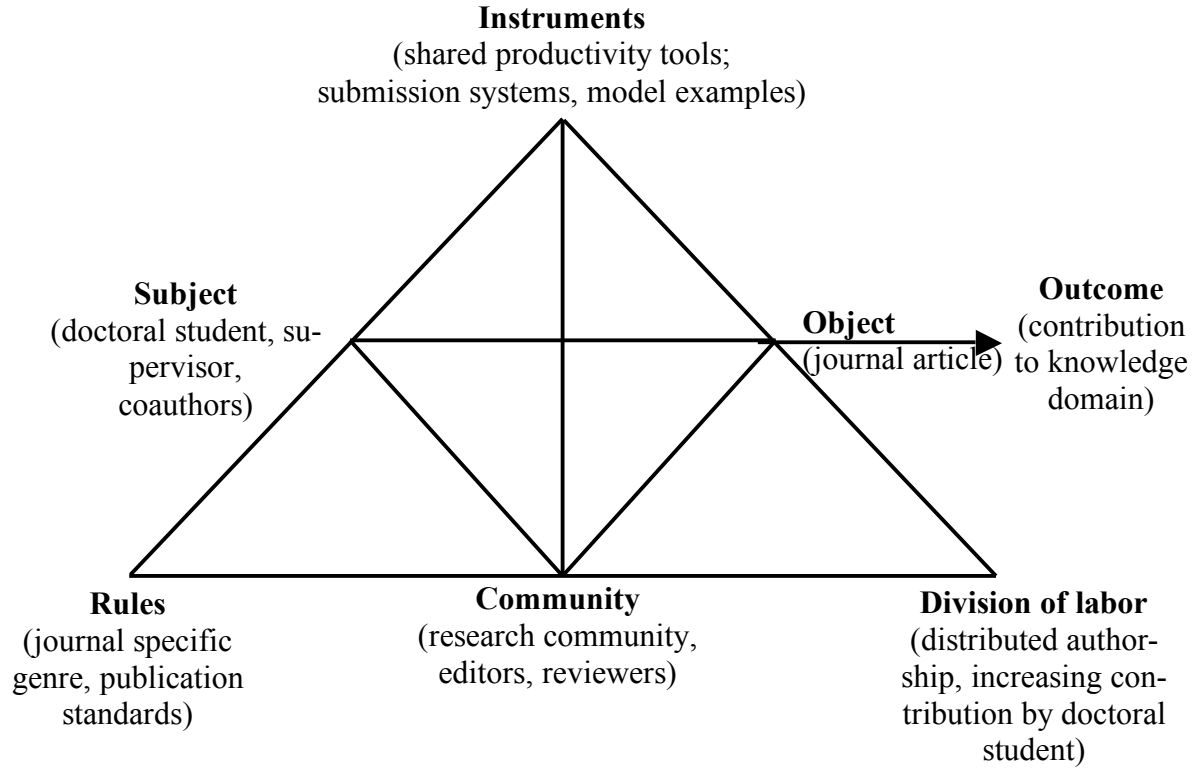

Figure 5. A rough outline of an activity system (Engeström, 1987) of expanded publication practices involved in journal science

Pursuing doctoral thesis and pursuing international scientific publication represent different types of typified textual practices, i.e., genre (Bazerman, 1988; 2004; Bazerman & Prior, 2005), that call for different types of competencies from the participants. Genre may be understood as temporarily stabilized but historically developing object-oriented textual practice. Rather than constraining creativity, as beginning academic writers sometimes assume, it channels and directs the participants' intellectual efforts in a way that elicits meaningful and effective production of scientific knowledge. The genre of an academic thesis is different from that of journal article in terms of the latter requiring very concise and compact presentation of arguments and following of discipline and journal specific conventions, rules, and rhetorical conventions (Hyland, 2004). Moving to production of journal science requires the participants to expand their genre sets and transform their overall genre system. Learning the corresponding repeated activity sequences and practices needed for producing adequate texts for mediating discourses, is likely to take time. Further, the investigators need to learn to work constructively, through several iterative cycles, on their manuscripts. A characteristic of the process is that often reviewers are somewhat external to the specific topic: Since they come from different contexts, the require changes in the manuscript, which differ from those of a thesis supervisor. In many cases, the referees' statements push or kick the investigator to take his or her inquiry further than she had initially been willing to go. Referees also typically encourage carefully stated limitations as to claims, tying them to the evidence collected. The

scientific referees are experts who have themselves published in the journal in question. They require changes to make the arguments clearer, better justified, logical in development, as well as grounded in a way that is acceptable to experts within a wider research context.

Learning to do scientific publication corresponds the process of adopting a cognitive-cultural operating system of academic research (i.,e., a disciplinary-specific activity system, see below); this is a difficult process to go through, but after a successful transformation, it may become an investigator's second nature. Consequently, after going through expansive transformation and adopting cultural scripts of publication (Figure 5) either by collective piggybacking within research communities or through sustained personal efforts, the doctoral students experience the novel academic practices as a part of their everyday activity and cannot understand what was so difficult about it.

The collective subject of academic research: Research community and laboratory

Modern academic research that appears to across disciplines increasingly takes place in communities and networks. The subject of knowledge creation is a community rather than an individual. In some cases the community is in the background (invisible college, Crane, 1972; textual community, Stock, 1990), whereas it is an intensively functioning spatio-temporally extended realtime system, more or less, in some other cases. Collectivization of research implies that socialization to academic knowledge practices takes increasing place through research communities that carry, bear, and cultivate corresponding social practices. Nersessian (2006, see also Miettinen, 2000; 2006) examined research laboratories as a complex cognitive-cultural system that consists of integrated arrays of senior and junior investigators, tools and instruments, methods and procedures, research materials and databases, and materially embodied epistemic artifacts. The systems are embodied in situated interactions taking place in and distributed across heterogeneous networks of humans and technological artifacts (see Clark, 2003; Hutchins, 1995). Taken together these resources, distributed in time and space, constitute an experimental system (Holmes 1996) that allows the laboratory to produce scientific knowledge in the research field in question. This cognitive-cultural system constitutes the basis of the knowledge-producing practices in question. Hence, instead of the human mind, we regard the laboratory as the problem-space needed for pursuing academic research. As such, it consists of investigators, instruments, laboratory methods, epistemic artifacts, research problems and lines of inquiry, and internal as well as external social networks.

The laboratory is embedded in a wider network of academic research communities and has intensive internal as well as external networking interaction in respect of investigators, instruments, research materials, and epistemic artifacts moving across the boundary. Mentoring and apprenticing practices constitute an essential aspect of the cognitive-cultural system. According to Nersessian (2006) novices become acculturated to the laboratory practices through an apprenticeship process that engages them in working to make various laboratory "constructs". Novel cohorts of students come to the laboratory, each of them having unique knowledge, experience, and interests that affect the collective research agenda. Their challenge is to identify problems that promise to advance the shared inquiry and open up fresh lines of investigation. In order to utilize distributed resources of the laboratory, they have to create a transactive memory (Moreland, 1999; Wegner, 1986) of the laboratory in relation to the epistemic entities worked on and establish collaborative relations and pursue research that capitalizes on the construct created by the experimental system in question (adapting, redesigning, creating constructs). Cognitive-cultural systems are "dynamic, evolving, and continually reconfiguring" as a function of personal learning and development, as well as advancement of collective inquiry. Innovations and knowledge advancement make tools, techniques, and shared practices transform constantly so that many characteristics of the system change.

The basic experimental system (Holmes, 1996) is, however, relatively stable. Technological and epistemic artifacts utilized in research develop more rapidly than other aspects of the experimental system. Trajectories of the participants and trajectories of developing instruments and technologies co-evolve and affect one another relationally.

Such distributed cognitive systems are close to epistemic cultures, as defined by Knorr-Cetina (2007, p. 363): *"The notion of epistemic culture is designed to capture … interiorized processes of knowledge creation. It refers to those set of practices, arrangements, and mechanisms bound together by necessity, affinity, and historical coincidence which, in a given area of professional expertise, make up how we know what we know. Epistemic cultures are cultures of creating and warranting knowledge."* We share with Knorr-Cetina (2007) a transition from examining knowledge as a representational product to understanding "knowledge as process" or "knowledge as practice" (p. 364). As Knorr-Cetina observed, the subject of modern academic research is collective in nature, to the extent of extremely complex experimental systems playing a crucial role in pursuit of research. Notwithstanding that Giere (2002a; 2002b; 2004) is correct in pointing out that there many reasons for not going very far in granting such group minds psychic characteristics, Knorr-Cetina's (1999) observations of the enlargement of the collective subjects are accurate.

Deep enculturation to academic research practices

What kind of learning is involved in the transformation involved in doctoral training in general and learning to pursue collaborative research in particular? The intelligence of knowledge-creating work does not (perhaps paradoxically) appear to reside mainly within the human mind – or to be an individual attribute – instead it is distributed, spread, across learning and transforming human agents, knowledge artifacts produced (Hakkarainen, Lonka, & Paavola, 2004), and in the shared innovative practices of working with knowledge ("knowledge practices", Hakkarainen, 2009; Hakkarainen, Ilomäki, Paavola, Muukkonen, Toiviainen, Markkanen, & Richter, 2006). By *knowledge practices*, in turn, we refer to personal and social practices related to working with knowledge The term "knowledge" is used in the broadest sense, to include what is explicit or stated in official discourse (e.g., approved texts), to what is implicit, informing one's habits (perhaps pre-reflectively) of expert working; and further yet to that which underlies the competencies of experts, for example, so called "procedural knowledge". In order to understand the fundamental role of social practices in academic research, investigators need, however, to go beyond merely addressing procedural knowledge (compare Thagard, 2005; Ludvigsen & Digernes, 2009).

The doctoral process may be examined from two perspectives. Firstly, it may be useful to think of it as a process of acquiring the *cognitive-cultural operating system of academic research* embedded in corresponding disciplinary practices. Secondly, we may examine the process of deep disciplinary enculturation and intellectual socialization that mediates the process. In what follows, we will examine these issues successively. Going through doctoral training involved extensive efforts across many years that lead to profound personal transformations, comparable to that of acquiring literacy. Following Merlin Donald (2000, see also 1991; 2001; 2004; 2007; see also Clark, 2003; Hakkarainen, 2003a), such learning may be seen as a process of re-formatting the human mind and the brain. Literacy in general and academic literacy in particular involves appropriation of a new functional system (Luria, 1974) across long-standing processes of intellectual socialization. Such formatting process changes the very architecture of the human mind and establishes a new "virtual machine" (Dennett) for pursuing complex culturally programmed rather than biologically given problem solving. Due to the super plasticity of the human mind, extensive cultural programming re-formats the functioning of the mind, beyond anything biologically determined. Whereas

such approaches as meme theory (Dawkins, 1976) acknowledge the cultural-historical nature of knowledge, Donald argued that such theories represent "cognitive solipsism" because only knowledge is assumed to be shared, and the mechanisms of the human mind are taken as given. Donald (2000) proposed that the very operating system of the literate mind is mediated through interaction with cognitive-cultural megastructures and networks. We agree with this approach. Although the operation system may be understood to represent activity system (Engeström, 1987), talking about "operating" system is heuristically valuable in terms of highlighting the fact that the very architecture and mechanisms of mind transform through appropriation and internalization of the system. Whereas the operating system may be internalized it is materially embodied and distributed across academic laboratory practices. While individual participants go through developmental processes that transform functioning of their brains structurally and functionally, we do not need to consider the developmental process to be solely 'mental' in nature: it can be given a materialist explanation in terms of cultural competences being materialized, based in a participant's cortical structures. Such operating system is embedded in the shared knowledge practices of the academic community as well as mastered by the more experienced members of the community. Doctoral training is a process in which a participant has to appropriate the operating system through sustained social participation as well as through sustained and deliberate personal efforts aimed at solving problems, carrying out investigations and production of knowledge. Although a great deal of improvisational efforts is needed from the participants, it is advantageous to newcomers to *assimilate an already existing operating system through collective doctoral training* rather than to try to create one from the scratch, in the way independent doctoral students often have to do by imitating practices of research communities from a distance. The advantage accrues to the community as well, in respect of increased output.

Growing up to become a researcher requires deliberate sustained efforts across many years, optimally taking place in disciplinary cultures or research communities. Such socialization involves parallel deliberate, conscious, and reflective top-down efforts as well as gradual bottom-up adaptation to cultural practices and transformation of the habitus (Bourdieu, 1980). This process involves sustained efforts of acquiring knowledge and expertise within one's field through long-standing deliberate efforts, which require approximately four hours of daily practice across ten years (Ericsson, Krampe, & Tesch-Römer, 1993; Weisberg, 1999; 2006). Further, new researchers are, in general, able to significantly change the genre only after they acquire its principles. Sustained intellectual socialization is needed in order to become able to make a creative contribution to the field. Holmes (2004) argued, "… *in science as in the arts, steady work at the discipline or craft is required to master a domain, and … only after such mastery has been attained is the scientist able to produce results that advance the field in which he has learned to practice at a high level"* (p. 55). According to Holmes, the ten-year rule may, however, be too rigid. This is because young doctoral students mastering novel methods and instruments are sometimes able to jump directly to the top after fewer years of practice (e.g., Meselson-Stahl experiment).

Deliberate practice is not a mechanical process but involves deliberate seeking of challenges, reflecting on and conceptualizing performance, intentional efforts of overcoming weaknesses and so on – frequently, under personal guidance of those already mastering the competence in question (Ericsson, 2006). Sustained participation in meaningful shared practices gradually and continuously transforms the participants' cognitive systems, even if the participants are not aware of the process. His or her neural networks adapt to frequently encountered patterns of stimulus, according to the priming effect, both meaningful and non-meaningful patterns of stimulus become activated. The emerging implicit or "tacit" knowledge (Polanyi, 1966) plays a crucial role in the participant's activity. Doctoral students are becoming socialized to their

academic field by practicing research activity and learning from available exemplars. During a long-standing developmental process, the participants' competences become, gradually, structurally coupled with the cognitive-cultural system of the laboratory (Tuomi, 2002). While this likely to be indicated in seamless integration of the participants' activity with that of the laboratory community, the interview may not be adequate method of assessing the process (because many collaboratively integrated aspects of activity become invisible to the participant).

The adoption, over time, of a novel operating system of academic research may be seen as an extended process: the transformation of one's habitus (Bourdieu, 1980; Delamont et al., 2000; 2001; Roth & Bowen, 2001a; 2001b), which provides a "practical sense" (or competence) of pursuing investigations. Whereas activities corresponding one's habitus are easy and effortless to do, doing something differing from it is extremely hard and difficult. Changing habitus on one's own is not impossible, but requires extended trial-and-error efforts embedded on cultural practices; the process is comparable with lifting oneself from a swamp by pulling one's hair. Going through the process by relying on collective support and assistance is much easier. Habitus appear to rely on human extensive resources of implicit learning (Schank, 1999); i.e., gradual emergence and activation of neural networks for recognizing meaningful pattern encountered in expert's activity. Such bottom-up processes involve priming; activation of repeatedly encountered patterns that does not fade in the same way as explicit learning and that concerns both meaningful and not so meaningful patterns encountered. Although such implicit learning plays a major role in the development of expertise, deliberate reflection and pursuit of learning are also relevant. Such efforts guide and direct human activity and, thereby, affect the extent and nature of implicit learning. In any given point of time, however, the deliberate top down efforts of learning are embedded in a whole sea of implicit learning and tacit knowing (Polanyi, 1966) that guide and constrain creative efforts. Creativity of professional researchers is based on habitus and associated functional systems that have been cultivated across years and decades; such intellectual socialization constitutes a great deal of scientific cognition.

The disciplinary activity system provides domain-specific knowledge practices that guide basic lines of pursuing inquiries, analyzing and interpreting results, and publishing the results. The practical sense concerning how to go about doing research in one's field may play a critical role in one's research activity; the actual investigations take place through the "dance of resistance and accommodation" (Pickering, 1995; Engeström, 2005) involved in interaction between human and material agency of inquiry. Outcomes of complex epistemic and experimental practices cannot be controlled; humans' intentions and their activity as agents play a crucial role. There appear, further, to be co-development of participants and the shared operating system of research (Nersessian, 2006). The evolving instruments of the laboratory are applied to emergent problems pursued by doctoral students and post-docs. Consequently, appropriation of the cognitive-cultural operating system is not a one-directional, mechanical, or straightforward process, but requires extended iterative and recursive efforts, overcoming of frequently encountered disturbances and tensions in the context of deliberately pursuing a novel lines of inquiry. It is rule rather than an exception that experimental systems fail to produce results (Knorr-Cetina, 1999; Delamont et al., 2000; Holmes, 2004); there is often a great deal of resistance coming from instruments, laboratory settings, and other encounters with reality. In order to make the system to work at all, the doctoral students have to engage in intensive tuning (Pickering, 1995), i.e., deliberate efforts to accommodate the resistance and making the system to work (Holmes, 2004, p. 7). There appears to be an intriguing instrument-object transition going on in respect of instruments becoming objects while being tuned and tinkered with (Holmes, 2004, 7). Making instruments

and experimental systems do what is desired requires a great deal of understanding of their developmental history and potentials (Nersessian, 2006). Each doctoral project involves stretching of the experimental system to novel and, frequently, unanticipated directions; this may open up "third spaces" (Gutierrez, Rymes, & Larson, 1995), i.e., novel lines of inquiry (McAlpine & Hopwood, 2009). The participants' developmental pathways toward becoming independent researchers are in dialectical interaction with trajectories of their evolving research instruments, technical artifacts, and the cognitive-cultural operating system (Nersessian, 2006).

The activity systems of academic research are embedded in experimental or investigative systems on which academic research rely on. Across long-standing processes of cognitive socialization, such systems start to restructure the very architecture of human mind. The investigator's methodological competences are deeply carved to the operating system (the system, so to speak, constitute the academic competences in question). Methodological changes may be required, e.g., in psychology, from qualitative to quantitative or from experimental to ethnographic study. Such horizontal methodological transitions are very difficult, perhaps more difficult than shifting one's conceptual paradigm (Kuhn, 1962). The analyses of Holmes (1996) indicate that it happens very seldom; there are not many investigators who would have succeeded in making such a lateral transition. Consequently, scientific progress tends to take place through new cohorts of doctoral students mastering novel methods and developing, gradually, corresponding novel cognitive-cultural operating systems. Rather than being a mechanical process, adoption of the cognitive-cultural operating system involves sustained, creative, and improvisational cognitive adaptation. It is a longstanding process, and, therefore, there is generally a ten-year silence before modest creative insights, not to say anything about culture-transforming ones, become available (Weisberg, 1999; 2006).

Beyond following familiar investigative pathways during apprenticeship, knowledge-creating interagency involves creating a novel trail for exploring a previously unknown territory. During such an investigative process, *"one proceeds step by step, each step guided by those taken previously and by uncertain intimations about what lies ahead"* (Holmes, 2004, xvi). Academic research follows the pattern of interrogative activity (Hintikka, 1999) because it involves pursuing research "*problems nested with problems"* (Holmes, 2004, xx), i.e., advancing to solve an initial 'big problem' by solving a series of subordinate problems. In practical problem-solving situations, investigators have to proceed before they know where the cognitive trail is going to take them: *"They must sometimes stumble along the way before they gain the sure footing that will enable them to stride with confidence toward the achievements that may mark them as major discoverers and leaders in their field."* (Holmes, 2004, p. 55).

Personal transformations involved in doctoral education

The essential core of doctoral education is not only engaging students in working with complex objects and providing them with corresponding sophisticated research instruments. Another intent is to produce growth of their personal and collective agency and transformation of their identity (Wertsch et al, 1993; Ratner, 2000; Holland et al, 1998). The participants have to develop a novel identity as a potential knowledge creator and a prospective academic researcher (McAlpine & Amundsen, 2008; 2009; Kamler & Thompson, 2007). As McAlpine and her colleagues (2009) have observed, doctoral students take part in multiple activity systems beyond their academic research community. They encounter heterogeneous institutional and disciplinary practices, take part in national and international conferences with corresponding practices; they are likely to pursue course work as well as functions as teachers themselves giving lectures and courses themselves. As well, they engage in family-related

activities. Negotiating conflicting demands and latent tensions between these activity systems is very challenging for the participants. Although such negotiations may be challenging, they also elicit the development of the participant's agency through providing unique experiences, knowledge, and perspectives for finding novel lines of inquiry provided that there is a reasonable chance of success. Although the present investigators acknowledge the importance of academic identity, it is essential not to restrict one's view; not to assume that personal transformation involved in academic research is only related to the objective of changing an individual's identity; the point of deep enculturation to the academic practices appears to be to constitutively affect the operating activity system of pursuing research, in both its individual and collective aspects.

Agency is characterized by experience-based social participation (past) that is focused on the future as well as the present; the former involves examining alternative trajectories and the latter involves negotiating the past and present projects today (Emirbayer & Mische, 1998, p. 963). Whereas collective doctoral work also calls for the development of agency, it is distributed and relational rather than merely personal in nature. As Delamont and her colleagues (2000, p. 125) observed, collective doctoral students describe their inquiry processes in collaborative "research group commitments" rather than in terms of "personal commitment and interest". Their academic activity takes place in a collaborative research community that pursues a collective research agenda sharing research objects, research instruments and experimental system, theories and analytic methods, as well as refereed co-authored publications. Although every doctoral student has to pursue his or her own doctoral research, a collaborative approach focuses on research problems inherited from the earlier cohort or generation investigators, some of them still working in a community and taking part in supervision. The problem under investigation is a part of research agenda of the supervisor, and it is closely related with parallel problems pursued by other doctoral students. Although each doctoral project is likely to be extremely challenging as such, doctoral students are pursuing the project by capitalizing on collectively developed experimental systems and shared knowledge practices, appropriation of which they often have to struggle across long periods of time. Because the project aims at generating and creating new knowledge, there is always a great deal of risk involved; collective pursuit of research never ensures success in innovation.

Edwards (2009; forthcoming) distinguished mere intersubjectivity from genuine collaboration. The former refers to processes of apprenticeship through which mature members of community assist newcomers in appropriating cultural practices and developing corresponding personal competencies. Whereas individual doctoral education involves such intersubjective processes of scientific supervision, collective doctoral investigation appears also to expand boundaries of such activity through involving coordinated collective efforts in pursuit of shared objects, such as inter-generational research problems, associated lines of inquiry, and co-authored publications. The collective approach capitalizes on distributed supervision in terms of shared practices guiding and channeling the participants' efforts and research community providing multiple vertical (between senior and junior researchers and horizontal (between peers) networking relations supporting real-time trouble-shooting of emerging problems and advancement of inquiry. Although the intersubjective processes of supervision are present, they are embedded in intensive pursuit of collective research objects by relying on complementary knowledge and competence. It appears that while *relational agency*, as such, is not a form of apprenticeship, it plays a critical role in collective pursuits of academic research. Following Edwards (2005), it may be defined in this context as a capacity to productively work with other researchers-practitioners by capitalizing on collectively distributed resources to support one's inquiry. It involves expanding and augmenting one's inquiry by seeking assistance from other community and network participants as well as providing sup-

port for the others when requested or deemed appropriate. Such agency goes, however, beyond shallow sharing of cognitive effort in deliberately focusing on advancing shared objects of inquiry. Relational agency is a matter of expanding personal agency; it is, says Edwards(2005) "a capacity to work with others to expand the object that one is working on and trying to transform by recognizing and accessing the resources that others bring to bear as they interpret and respond to the object" (p. 172).

In many ways, collective doctoral studies appear to be an excellent example of *object-oriented interagency* (Engeström, 2005) that involves intensive "dwelling" with complex research objects with assistance of intensive "connecting and reciprocating" across diverse boundaries epistemic and disciplinary, social and cultural in nature. The object-oriented nature of academic research appears self-evident and involves pursuit of historical-developmentally and socially shared research objects (i.e., genealogies of problems pursued by research community across cohorts of doctoral students; Holmes, 2004). Whereas collective doctoral studies take place in a core research community with relatively well-defined boundaries, the process involves, in many cases, integration of diverse lines of research and associated instruments, methods and theories. Moreover, the research effort is embedded on larger networks of research communities involving repeated boundary encounters in which collective doctoral students take part (e.g., through having external collaborators, supervisors, and co-authors). Without object-oriented interagency, it would be very hard to reach across "the dividing boundaries and gaps" between activity systems involved in the expanded research network (Engeström, 2005). The subjectivity relevant in collective doctoral education is collective subjectivity involving the following component processes and activities (compare Green, 2005):

- Formation of a dynamic, emergent system involving doctoral student, supervisor, collaborators in relation to shared object oriented work;
- Appropriating and tuning the experimental system to answer collectively posed research questions;
- Stretching the experimental system for answering new questions, producing new results in interaction with new perspectives and approaches of the doctoral student (making the system one's own in terms of innovative contributions);
- Formation of a transactive memory system that bears metaknowledge of distribution of knowledge and competence – strengths and weaknesses of human and nonhuman actors in the experimental system;
- Deliberately expanding the heterogeneous research network conceptually, methodologically or instrumentally (or data-wise) by seeking out new networking partners;
- Reflecting on interagency research and deliberately initiating novel lines of inquiry by challenging established truths and practices and opening novel personal lines of inquiry.
- Being empowered by collective agency (Bandura, 2006) facilitated by and through interagency research.
- Emergence, through interagency activity, of exceptionally strong networking linkages between supervisor and students and among doctoral students (often extending across lifetimes).
- Building collaborative intentionality capital (Engeström, 2005) regarding extended collaborative research pursuit with a high degree of trust and a deep sense of belonging.

As Delamont and her colleagues (2000, p. 65) pointed out, "the research laboratory operates upon *the principle of reciprocity*" that allows real-time merging and fusing of collective research activity. Beyond the epistemic dimension, the relational agency of collective research

involves an ethical dimension in respect of assuming collective cognitive responsibility (Scardamalia, 2000) for advancement of inquiry (Edwards, 2009). The collective approach guides the participants to share their collaborative efforts in conjunction with assuming mutual responsibility for getting the task completed. From such collaborative endeavors emerges a requirement of a relatively high mutual responsiveness without which collective activity would not advance adequately. Independent doctoral students may sometimes have to wait many months, sometimes even two years (sic!), for a supervisor's comments on their manuscripts; such is unthinkable in research collectives based on relational ethics and solidarity (Richie, 2007; Richie & Rigano, 2007; Roth, 2007; Roth et al., 2007). Without cultivating an academic "ethics of care" (Gibbs, Costley, Armsby & Trakakis, 2007, the concept goes back to Heidegger) it would be hard to change priorities for assisting those in need of support, by investigators who are themselves struggling to cope with many challenges of hectic research work. The development of relational agency appears to elicit a certain kind of academic "payback" ethics: researchers who have received a great deal of support in their own inquiry processes are generally more than willing to reciprocally share their knowledge and competence as well as engage in supporting joint activities with other community members; they assist those who are struggling. From this may, of course, emerge problems of slowing down of the agent's own inquiry. Rather than making the participants overly dependent from one another, relational agency elicits the participants' resilience by fostering both the development of their own expertise and a growing networked capacity to provide assistance to one another. The latter relies on their enhanced relational capacity of "knowing how to know who" (Edwards, 2005) that allows tailoring support to the specific needs and perspectives of the other.

Intensively collaborating research communities constitute collective cognitive systems in which it is hard to separate actors from one another. The participants' minds may at least partially merge so that they are living in each other's mind (John-Steiner, 2000). The participants' cognitions become structurally coupled with one another. Although investigators may analytically focus on individual agents and examine their development, determining their boundaries appears to be a non-trivial and challenging task. Mialet (1999) spoke about "*the distributed-centred subject*" (p. 574): She stated: *"... my goal has been to try to understand the subject in-the-making: that is, as he or she becomes (productive) through the distribution and re-appropriation of his or her extended body. ... Accordingly, the greater the number of elements to which an actor is connected, the more innovative he or she has the potential to be. Thus I show that the body of the scientist is the crucial site around which tools, techniques, human and narratives are simultaneously distributed (extended) and concentrated (singularized)"* (p. 575). Roth and his colleagues (2007) in turn, talk about participation of doctoral process as *"being as being singular plural"* [borrowing from Nancy (2000)] so that an individual agent cannot be absolutely separated from the group understood as a coherent whole ("singular plurality"); participants and the group reciprocally constitute one another as a totality. This appears to be one essential aspect of interagency involved in collaborative academic research.

Intergenerational expansive learning

The present socio-cultural approach to collective creativity acknowledges that pursuit of innovation and knowledge creation are materially, socially, and temporally distributed rather than mere mental and subjective processes. This enables investigators to capitalize on cumulative effects of collective rather than solely personal intelligence and creativity. Collective creativity can be examined at multiple levels from a) sustained pursuit of knowledge-creating inquiries, b) collaborative emergence of expansive epistemic practices, to c) inter-

generational cultural or expansive learning that super-charges (Clark, 2008) knowledge practices of new cohorts of investigators.

Rather than mere here-and-now insights, knowledge creation involves deliberate efforts across sustained periods of time. As Howard Gruber (1974; 1995) says, "Creative mind thinks its object constantly, it never rests": "Thinking about complex subjects is *organized over time*, over long periods of time" (Gruber, 1974, quoted by Holmes, 2004, xv). Consequently, creativity is related to long-standing object-oriented working. While actively pursuing inquiry within a domain, creative experts have daily intuitions and creative insight (Gruber, 1974). The present investigators argue that creativity and pursuit of innovation are historical-developmental matters. What ideas a person can produce today are related to the developmental history of his or her activity, involving both pursuit of materially embodied laboratory inquiries and expansive stimulation involved in analyzing, interpreting, synthesizing, and rising above of the results while publishing. Creative processes are organized according to an evolving network of research enterprises that allows organizing life in a way that elicits pursuit of innovation and knowledge creation (Gruber, 1974; 1989; 1995). An investigator utilizes the network in advancing one project by relying (piggy-backing) on competencies developed by another one. When advancement becomes difficult, the project may become dormant for a few years, to be activated again in a novel situation. Novel insights do not emerge randomly but through building on extended inquiry processes that one has gone through in the past.

Project pursuit and shared knowledge practices appear to be in a reciprocal interaction. Sawyer (2005; 2006) examined collaborative emergence taking place in social communities and networks. His researches, focused on jazz ensembles and improvisation theatres, have provided evidence of such collaborative processes (Sawyer, 2003a; 2003b). Collaborative improvisation is a very sophisticated form of collaboration. In improvised activity ideas emerge in interaction rather than within the individual participants. From stimulating interaction between two agents emerge ideas and thoughts that do not belong to any one of them but to the collective (Fleck, 1979, p. 42). In the background of innovations, there is an invisible collaborative network that breaks institutional, organizational and often also disciplinary boundaries. Many academically interesting innovations are radically distributed in that they are small sparks accumulating across time regardless of temporary breakdowns, ruptures, and discontinuities that push participants to re-interpret and re-implement emerging ideas, and open up novel lines of inquiry (Sawyer, 2007). Distributed innovations do not often emerge inside of laboratories or commercial organizations, but through sustained processes of using artifacts in practice, capitalizing on those aspects of them that turn out to be most valuable. Sawyer (2005) separated *the emergence paradigm* from *the structure* (addressing relations between social structures and agency) and *the interaction* (reducing relations between structure and agency to mediating interaction) paradigms. A central characteristic of the emergence paradigm is to examine stable (group cultures, discursive routines, shared practices, collective memory) and ephemeral (temporally varying patterns of participating and interacting in relation to evolving themes and contexts) emergents that dynamically appear in the course of collective activity.

In psychological research, investigators have become interested in inter-generational learning. Such higher-level learning processes play a crucial role in academic research as well. The argument of the present investigators is that such collaborative emergence plays an important role in formation of expansive scientific research communities. Participation in such communities elicits creation of novelty and pursuit of knowledge creation, because it capitalizes on cumulative collective sparks that emerged across long periods of time and crystallized and materialized to research instruments, experimental systems, and shared knowledge prac-

tices. Pursuit of innovation and knowledge creation requires structures and practices, but these should not be too rigid or inflexible; that would prevent collaborative improvisation needed for solving emergent problems (Sawyer, 2003a). The whole system is a part of creative process rather than mere participating individual agents. Academic research communities rely on dynamically evolving practices rather than stable practices, rigid procedures or given constellation of skills. Expert communities rely on "weakly determined, unstable, explorative, and problem-laden practices that are once in a while innovative" (Knorr-Cetina, 2001, p._). It may be argued that in the case of cutting-edge research communities, innovation and pursuit of novelty are themselves transformed to shared social practices by making deliberate and systematic re-invention of practices into a social practice (Knorr-Cetina, 1999, 2001). A central characteristic of such activity is the systematic pursuit of novelty and constant working at the edge of competence (Bereiter & Scardamalia, 1993).

Whatever creative processes one is able to engage in today capitalize on the knowledge, instruments, and practices of earlier generations of investigators (inter-generational learning): *"Every inventor, even a genius, is also a product of his time and his environment. His creations arise from needs that were created before him and rest on capacities that also exist outside of him. This is why we emphasize that there is a strict sequence in the historical development of science and technology. No invention or scientific discovery can occur before the material and psychological conditions necessary for it to occur have appeared. Creation is a historical, cumulative process where every succeeding manifestation was determined by the preceding one"* (Vygotsky, 2004).

Epistemic communities carry or bear knowledge and wisdom accumulated across many years; such cultural (Tomasello, 1999) or expansive learning (Engeström, 1987) plays a crucial role in collective creativity of academic research. Inter-generationally cultivated know-how supercharges the subsequent community members' knowledge practices in a way that elicits academic excellence. New cohorts of doctoral students entering such research communities are directly socialized to advanced epistemic practices cultivated across years. Undertaking such an approach, collective doctoral students, so to say, jump onto an already moving train, an action that greatly hastens the development of their academic knowledge practices and scientific cognition. This can, for instance, be seen in the process of acculturating new community members directly to advanced publication practices without having to themselves go through similar frustrating trial-and-error processes as the original innovators. In this regard, academic research may be seen as a relay race in which a person, in a good setting, gets "a flying start". In spite of tremendous personal efforts across long periods of time required from the participants, getting access to higher-level knowledge practices makes a difference. Exceptional academic achievements become attainable when ordinary agents are provided with an access to extra-ordinary knowledge practices cultivated by many generations of investigators.

Although the collective creativity embedded in academic knowledge practices has not been carefully investigated, this effect is well known among investigators' of academic research. Apprenticing within a laboratory of highly regarded investigators provides one with a privileged access to extra-ordinary knowledge practices often cultivated across generations, which may provide cumulative advantages across one's career. Scientists of our time acknowledge, for instance, that *"the most effective way to win a Nobel Prize is to be trained by a Nobel Prize winner"* (Holmes 2004, p. 28). There are many examples of sequences of several generations of Nobelists trained by a scientist who himself had won the Prize. Investigators know such lineages going through four generations of exceptionally productive researchers, and the historical-developmental depth of academic excellence would go many generations further if the Nobel Prize had existed in the past. Learning sophisticated experimental practices, includ-

ing delicate experimental skills, requires years to cultivate. For achieving academic eminence, it is essential to get access to cutting-edge knowledge practices particularly *"observing at close range how the master does it"* (Holmes, p. 28); here it is, perhaps, essential to acknowledge that we are not primarily talking about the master's practices but also collective practices of the research community created by him. Accessing such practices provides a fast track for learning of high quality academic research capitalizing on cumulative expansive learning across years and decades. Apprentices of eminent scientists have privileged access to unique learning opportunities that elicit the growth of their talents and competencies. Working with an eminent investigator provides cumulative advantages important in one's scientific career through having expansive learning experiences, encountering exceptional challenges, and receiving support and facilitation. An important aspect of distributed cognition is to create strong networking connections with the leading figures of the field by sharing connections of the master. Such experiences elicit personal and collective agency (Bandura, 2006) with corresponding attitudes and efficacy beliefs related to pursuing challenging complex problems by systematic inquiry.

An critical aspect of collective creativity appears to be gradual emergence of extremely tight *epistemic criteria of accomplishment* (Hakkarainen, 2005; Olson, 2003) that guide inquiry activities and internal and external evaluation of achievements. Krebs wrote: *"Above all, what they* [the masters] *teach is a high standard of research"* (quoted by Holmes, 2004, p. 31). As one of the most eminent Finnish research leader stated: "*Objectives, of course, need to be places the most ...high as can be imagined. Objectives need to set high and all the time focus on quality instead of quantity. And time doesn't make a difference in the sense that you can't work to a poor standard to get things done faster, you need to start from the basics. You need to understand what you're doing. You need to develop that sense of the problem. This is very important. You have to be, you have to at least read everything well – relevant, a lot of relevant reading, so that you have, hopefully it becomes a sense, a question arises about how to take this further."* Members of expansive research communities assume qualitatively much more demanding epistemic standards of evaluating inquiry than most of the other investigators or communities. Something that is considered to be a minimal level of accomplishment at such research community may be regarded to represent an exceptionally high-level achievement by outsiders who do not share similar history of expansive inquiry. Consequently, members of such communities tend to follow investigative trails further than the others were willing to do and often deliberately attempt to break into a novel domain of knowledge and inquiry while pursuing academic research. It may be proposed that there is some sort of metaskill that guides direction of research activity (Hakkarainen, Palonen, Paavola, & Lehtinen, 2004; Muukkonen & Lakkala, 2009) rather than simple "creative" talent or some other sort of individual characteristic. It appears to be an emergent result of the sustained effort of pursuing expansive knowledge practices.

An investigator's academic career involves a long apprenticeship *"normally under guidance of a mentor who can lead the emergent scientist to a place near the forefront of a problem of current interest"* (Holmes, 2004, p. xix). Such apprenticeship provides an access to cutting-edge knowledge practices and associated cognitive-cultural operating system of academic research. In order to initiate a novel line of inquiry, cross-fertilization of methods, instruments, experimental systems and other aspects of the operating activity system may be needed. Toward that end, many researchers enter into a new apprenticeship relation as a relatively more independent and mature postdoctoral investigator. Many investigators have apprenticed under several masters; moving from one research community to another one and changing, also university. One of the specific characteristics of Finnish academic culture is, however, that investigators tend to stay across their whole career at the same department and

same university (in addition to periods of being a visiting scholar abroad); presumably a more dynamic culture in which investigators would move across academic knowledge practices could elicit more innovation.

Collective creativity of academic research appears to rely on the dialectic between personal and collective pursuit of knowledge creation (Engeström, 1999a). Only through capitalizing on collective achievements, does successful personal pursuit of knowledge-creation becomes available. In order to analyze personal-collective dialectics of knowledge creation, it is essential to examine "investigative pathways *"The metaphor of the research trail – or ... "the investigative pathway" – both describes and can contribute to our understanding of the personal trajectories of individual scientists within the larger investigative movements in which they take part. The double face of each branch of science – as, on the one hand, a collective "long march" by a group of specialists sharing a discipline and pushing ahead altogether along a "frontier", and, on the other hand, as the private struggle of each individual within that group to find a distinct place and to produce original discoveries, conclusions, and other claims through which he can make recognized contributions to the movement – provides the creative tension around which all our stories about the "progress" of science somehow resolve."* (Holmes, 2004, p. xvi).

Expanding the collective model to social sciences

To summarize, academically relevant creativity and innovation are best seen as not lying within the human mind but embedded in shared knowledge practices cultivated by research communities. We have proposed that knowledge practices, though sometimes just supporting routine learning (transmission), at their creative edge diverge from other routine social practices in that they take place in specific purposefully dynamic and fluid settings designed for the furtherance of innovation and knowledge (Knorr-Cetina, 1999; 2001). Rather than relying only on mere mundane habits or repeated routines (that may also be needed), such practices are aimed at solving emergent problems and constantly pursuing novelty and innovation. The driving force of the development of such practices is, as we have said, a constant dance between resistance and accommodation (Pickering, 1995): from encounters with reality emerge resistance, accommodation of which require deliberate efforts of transforming shared instruments and practices so that the system works. The pursuit of emerging networks of projects in a changing world through reliance on epistemic competencies created spontaneously leads to frequent disturbances, tensions, breakdowns, and contradictions. Solving these requires the reciprocal tuning of material and human agency (Pickering, 1995; Holmes, 2004; Engeström, 2005).

Emergence of a collaborative research culture requires profound social transformations addressed above. If one may consider the collective zone of proximal development of educational research (Engeström, 1987), we would like to argue that it involves creation of hyper-collaborative research communities that share everything from publications to citations so as to facilitate advancement of the whole research community. Pursuit of journal science is its own activity that is very hard to learn on one's own. Doctoral students can, however, be immediately immersed with journal science when entering a research community to pursue graduate or post-.graduate studies. Co-authoring plays a crucial role in collective doctoral education; it is the principal method of socializing new cohorts of doctoral students to journal science and practices of international scientific publication (Morrison, Dobbie, & McDonald, 2003). Co-authoring involves senior researchers a) sharing a part of credit concerning collective achievements, b) investing a part of their time for coaching newcomers; initially to a significant degree, latter of less and less as skills are growing, c) provides expansive learning opportunities and emerging challenges for the newcomers.

Our experiences indicate that if a doctoral student requires substantial assistance in creating his or her first article (perhaps 70% was contributed by the supervisor and senior colleagues), his or her own contribution grows very rapidly so that he or she does not need assistance any more in the context of third and fourth article. Each co-authored publication provides expansive learning opportunities for the participants; it is essential to provide all community member opportunities to take up such challenges – and push and kick them to do it when necessary. The strength of hyper-collaborative communities is in extensive re-mediation of the participants' activities that the participants cannot come up on their own. It appears that the collective doctoral education provided a good basis for creating strong inter-generational research traditions because it allows accumulating collective academic record. Such an approach appears also to be a productive line of developing publication practices of CRADLE.

The present discussion concerning doctoral education of social sciences in general and educational research in particular appears to have, in a great extent, taken the format of doctoral thesis as given (Shulman, Golde, Conklin Bueschel, & Carabedian, 2006; Evans, 2007; Richardson, 2006; Berliner, 2006). It is complained that doctoral education has too strongly been oriented toward basic academic research and pursuit of academic articles. Many investigators highlight the importance of integrating academic research more closely with solving of complex professional problems emerging from the innovation-driven society. Toward that end, some countries have established "professional" doctoral programs. Although the present investigators do not necessarily question such efforts, they would like to question the explicit or implicit assumption according to which collaborative pursuit of journal articles would somehow inherently be "academically oriented" and, thereby, in conflict with meaningful "professionalization" of doctoral education. We propose that a capacity to present compact and reasoned arguments that have gone through a peer reviews is important for all of us. Therefore, we argue that the collective model of doctoral education addressed in the present article fits very well in various domains of social science, including ones with tight links between the academy and the professional life. It is interesting that a vision of eliciting the collective model of doctoral education do not appear anywhere in the literature reviewed (we are planning to deliberately try to trace such suggestions by pursuing deepening cycles of review). Suggestion by Walker and his colleagues (2008) for improving quality of doctoral education by eliciting intellectual communities appears to be a direction desirable from the perspective of the present investigation. Going to the collaborative publication culture with articles does not and should not exclude the possibility of making monographs, when appropriate. In order for heterogeneous doctoral studies be successful, those should be embedded of diverse knowledge practices.

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