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CHANGES IN KNOWLEDGE CULTURES AND RESEARCH ON STUDENT LEARNING
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ABSTRACT
This paper discusses how contemporary changes in knowledge cultures and practices alter conditions for student learning in higher education and what this may imply for research on student learning. Drawing on perspectives from social studies of knowledge, it is argued that the general emphasis on science in society generates an increased research orientation also in professional programs and brings with it a focus not only on science-based knowledge but also on the investigative processes through which knowledge is produced and validated. Changes are also related to the emergence of advanced technologies that allow knowledge to circulate quickly in information networks. On its way, knowledge in such "global forms" provides new arenas for engagement as well as resources for community formation. As a result, environments for learning become extended and comprise a multitude of sites and practices that may coexist and interact in complex ways. To understand how students of today are inducted into expert cultures and develop expertise is thus an important topic for research. The paper examines how these issues have been addressed in research on student learning and suggests that analytical perspectives and resources developed within social studies of science may be employed to supplement existing research.

CHANGES IN CONDITIONS FOR LEARNING
Student learning is an increasingly important topic in higher education policy and research. Questions about the quality and effectiveness of educational programs when it comes to preparing students for the world of work, and about ways of engaging and supporting students on their way towards developing expertise in their chosen field of knowledge, lie at the heart of the educational mandate in the era of the knowledge society. At the same time that these questions come to the forefront, the environments in which learning and expertise development take place are getting more complex. This is partly related to the dynamics of knowledge itself. As pointed out by social scientists, the way knowledge production is linked with the economy makes advancements in knowledge emerge from numerous sites within and beyond educational institutions and research communities (Bechmann *et al.* 2009). Furthermore, the ubiquitous presence of information technologies allows the products of these activities to spread rapidly across institutional and geographical boundaries. As noted by Collier and Ong (2005, p. 11), more abstract and symbolic modes of representation give rise to "global forms" of knowledge: that is, forms that have a "capacity for decontextualization and recontextualization, abstractability and movement, across diverse social and cultural situations and spheres of life." Such forms of knowledge circulate quickly in information networks, and on their way they provide new arenas for engagement as well as resources for community formation.

An important driver in the current dynamics of knowledge production and dissemination is also the co-evolvement of new insights and new doubts. While scientific knowledge is believed to provide conclusive answers to societal problems, it is also generally marked with uncertainty and ambiguity. When new results are achieved, they often generate new questions and a need for further knowledge advancement (Knorr Cetina 2007). Fields of expertise are thus marked by stability and instability at the same time, in the sense that their histories and established collective knowledge regulate practices of knowledge production, while new advancements may question the "givens" and call for integrative actions in the expert community.

In the wake of this, the knowledge worlds in which educational programs are embedded are becoming more extensive and complex. Students in academic as well as professional programs are presented with knowledge and ways of thinking that are linked with dynamic and geographically dispersed ecologies of knowledge. These wider worlds contribute to defining relevant knowledge and competencies. At the same time, the resources they offer need to be explored and localized in specific activities to become meaningful to students. Moreover, as new technologies and advanced instruments are increasingly used in higher education and in private life, we cannot take for granted that students' participation is bounded to given sites. Technologies mediate participation across settings and may bring students in contact with distributed communities that relate to the domain or expert culture but exist external to the educational institution (Ludvigsen *et al.* 2011; Francis 2010). Educational programs are, in this respect, more than formal instructional settings; they also provide access

points to "disciplinary networks" of knowledge and practices through which people come to participate in multiple ways (Nespor 1994). Such networks could, for instance, include Web-based discussion forums, the activities of expert groups in professional organizations, and work practices of various kinds.

In a wider perspective, the relationship of education to work and the ways in which expertise is valued and comes into play in working life are also changing. One aspect of this is the increased presence of experts in society, which is related to the general rise in educational levels in the population and the development of new fields of expertise (Giddens 1991; Brint 1994). Equally important, however, are the cultural shifts that emerge in a society that places knowledge processes at its core. As noted by the sociologist Karin Knorr Cetina (2001, 2007), development towards a knowledge society brings with it a general focus on knowledge, not only in terms of products utilized to solve various kinds of societal challenges but also in terms of the modes of knowledge engagement. In the words of Knorr Cetina (2001, p. 177), the emergence of the knowledge society thus "involves more than the presence of more experts, more technological gadgets, more specialist rather than participant interpretations. It involves the presence of knowledge processes themselves (…), it involves the presence of epistemic practice."

She describes this development as a "spillover" of epistemic cultures into other spheres of social life and points to how people increasingly engage in observing and analyzing phenomena, thereby validating and developing knowledge as part of their everyday life and work. This often involves modes of practice that historically have been associated with science communities. Moreover, it involves a shift in collective mentalities and ways of thinking about knowledge, in which transparency in knowledge production and processes—which traditionally has been a core value in science communities—now is requested across occupational sectors and in different types of work (Knorr Cetina 2007).

These developments reflect new relationships between science and society, which are also likely to alter constitutive mechanisms of community formation in higher education. Moreover, they bring an extended epistemic orientation to higher education and work, through which the notion of mastering epistemic practices comes forward as an ideal not only for students in academic programs but increasingly also in higher professional programs. For instance, graduates from programs in engineering, nursing, teaching, and accountancy will more often be expected to select, justify, and validate knowledge in the context of work and to engage themselves in opportunities for improvement. Also, respective educational programs in these fields need to prepare students for these competencies. As proposed by Goodyear and Zenios (2007), a main task for higher education today is to develop students' capacities for understanding and creating knowledge in different settings by developing what they call "epistemic fluency."

During the last few decades, the importance of involving students in epistemic practices and research-like activities has been generally acknowledged in higher-education policies and practices. The report of the Boyer commission (1998) generated a range of initiatives to secure research experience for undergraduate students in research universities in the US and has parallel developments in Europe (Elsen *et al.* 2009; Healey and Jenkins 2009) and in Australia (Brew 2010, Zimbardi and Myatt 2012; iFirst). This idea also seems to have spread to undergraduate education more generally (Hu *et al.* 2008). Moreover, the idea of considering disciplines and expert domains as not only comprising specialized knowledge but also distinctive knowledge processes seems to be gaining ground in several areas. It came, for instance, into view in a recent report from the US National Research Council on what is termed discipline-based educational research (DBER) in science and engineering:

"In part, science may be thought of as a vast and powerful compendium of factual information, concepts, principles, and laws that describe the nature of the universe and its inhabitants. But science also comprises a set of investigative processes, or ways of empirically and systematically studying the natural world, to advance the collective understanding of its order. These investigative processes—which we refer to as practices—and the knowledge gained from their application are critical components of scientific disciplines. Without those investigative practices, there would be no new scientific and engineering knowledge. Thus, an understanding of the attributes of science and engineering practices is vital, as is imparting them to new generations of learners." (Chapter 7, p. 1, Advance copy version)

In the wake of this, understanding how students of today become acquainted with the principles for producing and validating knowledge in specific domains and develop as skillful practitioners capable of identifying, exploring, and utilizing knowledge in relevant ways emerges as a critical topic for research. The general emphasis on involving students in epistemic practices and research activities, however, does not necessarily mean that these forms of engagement have been reflected in research on student learning. The remainder of this paper will first examine some characteristic features of dominant research strands in the higher-education literature and their ways of addressing the relationship of knowledge practices to learning. Next, it will consider whether analytical perspectives and resources developed within social studies of science can be employed to supplement existing research.

RESEARCH ON STUDENT LEARNING IN HIGHER EDUCATION: SOME DOMINANT TRENDS

Research on student learning is potentially widespread, as it may be addressed in several research contexts such as higher-education studies, cognitive science, and discipline-specific research. Hence, it is not the ambition of this paper to provide a

comprehensive review, but rather to discuss some dominant trends in this research field and suggest some directions for the future. I will commence by looking into how the topic is addressed in higher-education research journals, followed by some examples from discipline-specific research.

Specialized journals for higher-education research exist in several country contexts, and it has its strongest foundation in the English-speaking countries. A general depiction of this research field is provided by Tight (2007), who conducted a comparative review of articles published in leading higher-education journals within and outside North America in the year 2000. Here, the "non–North American" category refers primarily to UK and some Australian journals.[1] Tight found significant differences between the geographical contexts in terms of topics, levels of analysis, and research approaches. In North American journals, student experience was a dominant theme that accounted for 33% of the published articles in the given period. In the non–North American journals, course design was a dominant theme addressed in about 25% of the articles. While the North American sample by and large focused on analysis on the national and institutional level (86% in total) and barely focused on the course level, around 15% of the articles in the non–North American journals addressed the course level. Differences also appeared when it came to methodological approaches, with survey studies and multivariate analysis accounting for 62% of the articles in the North American sample, compared to 29% in the non–North American journals. The latter group was, in contrast, more marked by document analysis and interviews, which may correspond to the greater emphasis on analysis at the course level in this sample. Of special interest for this paper is that the theme of "knowledge" was scarcely present across the samples (2-6%) and that relatively few articles had teaching and learning as their thematic focus (5% in the North American sample and between 9% and 15% in the non–North American journals). Common for the two samples was also that few studies seemed to rest on ethnographic or observational methods, although the number of such studies is not clear from the categorization employed by Tight.

Given the restrictions in time and type of journals, this cannot of course be taken as an inclusive account of higher-education research and ways of addressing student learning. More domain-specific studies of student learning are likely to appear in specialized journals about law studies, engineering education, medical education, and the like, and cutting-edge research on learning published in specialized journals for educational psychology and learning sciences may include studies conducted in higher-education settings. Nevertheless, we may say that the main publication channels in higher-education research in the given period were dominated by studies that focused on aggregated data at the institutional and systems levels. When the course level was the focus, the methodological approaches seemed to favor document analyses, possibly supplemented with interview data. Few studies included in this review looked at students' learning processes as they unfold through participation in knowledge practices.

A more recent overview that focuses exclusively on research on student learning in higher education is provided by Haggis (2009a, 2009b), who reviewed studies published in three leading journals about higher-education research in the period 1970-2007. The selected journals were *Higher Education (HE), Studies in Higher Education (SiHE),* and *Teaching in Higher Education (THE).* The review was performed as a content analysis, starting with the ways in which learning was conceptualized in the article titles and then identifying what models and research approaches they draw upon. Haggis has also compared his analysis of publications in these journals with publications in two main North American journals (2009a) and with research published in the related areas of adult education and sociolinguistics (2009b). Moreover, the results are compared with key theoretical moves in psychology and sociology in the same period of time (Haggis, 2009b).

Haggis' analysis shows that research on students' learning in higher education has been dominated by phenomenographic approaches in the given period. This strand of learning research has been developed specifically within higher-education research and grew out of the work of Ference Marton and his colleagues in the 1970s and 1980s (Marton and Säljö, 1976a, 1976b; Marton, Hounsell, and Entwistle, 1984). In this tradition, learning is investigated from the students' perspective, with an interest in revealing the variations in how students understand learning content and the approaches they take as learners (Marton and Booth 1997). Learning is, in this research, seen as a cognitive phenomenon that is often examined by way of questionnaires and interviews. This has led to important insights about how students differ in their learning approaches, which have been conceptualized as deep, surface, and strategic. Moreover, it has identified significant factors that call for teachers' attention, such as how course work can be designed to support in-depth engagement and critical reflection among students (Entwistle and Peterson 2005).

Socio-cognitive perspectives have also guided other powerful strands of research on student learning in higher education. In particular, this is reflected in research focusing on self-directed learning and, more recently, epistemic beliefs (e.g., Schommer-Aikins, Duell, and Barker, 2003; Muis and Sinatra 2006; Bråten, Gil, Strømsø, and Vidal-Abarca 2009). This research has accounted more explicitly for knowledge and identified generic as well as domain-specific issues of critical importance for students' learning and conceptual understanding. For instance, it has shown that students who hold more

[1] The targeted journals were: *Journal of Higher Education*, *Research in Higher Education,* and *Review of Higher Education* in the North American sample; and *Studies in Higher Education*, *Higher Education Research and Development* and *Higher Education* in the non–North American sample.

complex beliefs about knowledge and knowing are more likely to handle complexity in information from multiple sources and to develop a comprehensive understanding of ill-structured phenomena. This research has also pointed to how differences between students may increase over time, as students who have sound conceptual knowledge and metacognitive skills are more likely to handle complex tasks and to benefit from instruction. Hence, it contributes to explaining important differences in students' achievement and how those develop over time.

Also common for the research strands described above is that they tend to apply methodologies in which data from individual students and/or teachers are collected through surveys or interviews. Hence, although we have learned important lessons about the different approaches students take as well as about how different types of conceptions and beliefs influence student achievement, less is known from this research about how students develop expertise and conceptual understanding by participating in specific knowledge practices. Moreover, collaborative knowledge practices and engagement across settings are among the issues that tend to fall out of scope.

The above-mentioned report on discipline-based educational research in science and engineering (US National Research Council 2012) reveals that these issues are also understudied in educational research that takes the discipline as a point of departure. Moreover, studies in this field that do focus on knowledge practices often do so without employing an explicit theoretical perspective on learning. Pointing to a lack of studies that address student learning in inquiry-oriented activities and in settings marked by real or open-ended problem solving, the report draws the following conclusion:

For most of the disciplines examined in this report, the research on how students learn in laboratories or in the field—where they are likely to engage in science and engineering practices—is scarce. Additional research is needed to better understand how to measure and promote proficiency with these practices, and to explore relationships among practices and other outcomes such as overall understanding of concepts, practices, and ways of thinking of science and engineering. (Chapter 7, p. 7, Advance copy version)

Hence, it is suggested that researchers should study a wider variety of opportunities that engage students in science and engineering practices (ibid.).

Haggis (2009a,b) and Ashwin (2009) both point to how research on student learning in higher education has employed a somewhat narrow scope of questions and methodologies, compared with other fields of social science and educational research. The turn towards sociocultural and interactional perspectives that emerged in other fields during the 1980s and 1990s has not been taken up in higher-education research to the same extent. In addition, the development of network theories and approaches that have taken place in sociology during the last decades are not much reflected in research on student learning in higher education. This leads Haggis (2009b, p. 389) to conclude that research into learning in higher education has not accounted sufficiently for "'the fleeting', 'the distributed', 'the multiple' and 'the complex'."

There are, however, some noteworthy exceptions to this picture. One is the long-term ethnographic research program, conducted by Janet Donald and her colleagues (Donald 2002), that provides a thick description of the ways in which students in 16 courses across 8 disciplines are introduced to core principles in their field of expertise and, through this, learn to think like experts. The analyses focus on core concepts around which the knowledge activities evolved, the knowledge structure of the course content, its validation principles, and methods of inquiry (e.g., hermeneutics, problem solving, critical reasoning, experiments, examining expertise through personal models or action schemes). The study reveals how "learning to think" implied quite different things and came with different expectations for students in the various disciplines. For instance, while systematic reasoning based on precedent cases was at the core of engagement with knowledge in law, and problem solving through modeling and procedural exploration was significant in engineering, text-based criticism and creativity in a hermeneutic mode was important in the humanities. By focusing on issues such as validation principles and methods of inquiry, this study addressed core aspects of the epistemic practices that constitute a field of expertise. With respect to students' learning more broadly, however, it can be noted that the study primarily focuses on course content and activities and their inherent demands. What it means to think like an expert in the different domains is highlighted, rather than the processes through which such capabilities are developed and commitment to the expert culture is generated.

An unconventional study of the relationship of knowledge to learning is presented by Nespor (1994), who investigates how students are mobilized as learners in two undergraduate programs of physics and management by way of an ethnographic approach. Drawing on actor network theory in combination with other sociocultural perspectives, Nespor (1994, p. 131) defines learning as segments of "knowledge in motion" that "follow the shapes of more stable institutional or disciplinary networks." The analytical focus is on the socio-temporal networks of relationships that produce and reproduce educational tools and practices such as lectures, presentation sheets, notebooks, and social arrangements in auditoriums and classrooms. The ways these elements are enacted and acted upon constitute trajectories that differ in their socio-spatial outreach and shape how students are mobilized and become enrolled in distinct ways. Although Nespor's focus is on two specific undergraduate programs, the analytical approach utilized in this study is sensitive to how the material tools and practices enacted in these programs are interlinked with wider networks of knowledge. The programs are conceptualized as regions in more complex networks, which simultaneously "concentrate student activity within bounded material organizations

of space-time" and link students to "distant sites of disciplinary practice through representational organizations of space-time" (p. 133). An important distinctive feature of educational programs is thus how they arrange for different and often simultaneous modes of engagement. As Nespor states (p. 9), "Communities aren't just situated in space and time, they are ways of producing and organizing space and time and setting up patterns of movement across space and time." This study contributes with new insights by turning the usual analytical focus "upside down" and tracing the networks of knowledge and practices rather than individuals' engagement. It also contributes to our understanding of disciplinary differences by focusing on space and time relationships rather than on epistemic principles and strategies. Consequently, it reveals patterns of knowledge organization at the program level but does not attempt to reveal how students develop competencies and expertise by participating in the activities and trajectories offered.

STUDENTS' RESEARCH EXPERIENCES AND ACADEMIC ENGAGEMENT

In the last decades, a strand of research has been developed which targets the student experience in connection to research and inquiry-oriented activities. Following from the suggestions provided by the Boyer commission (1998) in the US, increased attention is being devoted to theorizing and analyzing the effects of involving students in research from their very first year as students. A core idea of the Boyer commission's report was that learning evolves through processes of inquiry, and students should thus be involved in inquiry-oriented activities from their very first year. Similar initiatives have been put forward in other national contexts, such as in Europe and Australasia, and have given rise to a range of studies that attempt to reveal the types of research experiences available to students as well as factors that are critical for the fostering of academic engagement. There seem, however, to exist some differences in how participation in research is categorized and described, and different terms are used to conceptualize relationships between research, teaching, and learning—such as research-teaching nexus, undergraduate research, inquiry-based learning, and problem-based learning. These differences are also reflected in the choice of research questions and units of analysis in research.

Elsen *et al.* (2009) examined strategic documents and educational policies in leading European research universities and found that although the connection between research and teaching was generally emphasized, a different emphasis was placed on the research process, the research outcomes, and the social context (i.e., the community of scholars) in which research takes place. These authors underscored the importance of moving towards a participatory model in which students are provided with opportunities to conduct research and, through this, become members of disciplinary communities.

Spronken-Smith (2010) focused on inquiry-based learning (IBL) and argued that, despite several differences in how the term is used, most researchers seem to agree that the following aspects are important: Learning is stimulated by a question or issue to be explored, the teacher takes the role as a facilitator rather than presenting knowledge and information (i.e., what has been termed a student-centered rather than a teacher-centered approach), and the student takes an active role in exploring the question or issue at hand through processes that involve the construction of new knowledge and understanding. According to this author, IBL can be distinguished from undergraduate research in the sense that the former requires a student-centered approach, while the latter in principle might be faculty-led without involving the students in the more inquiry-oriented ways of working. The framing of such activities may, however, be more or less oriented towards collecting information to shed light on known problems, and more or less discovery-oriented, with the intention of producing new knowledge. Spronken-Smith and others discuss this in terms of more or less structured inquiry-based activities.

In a meta-analysis of IBL at different institutions (Spronken-Smith *et al.* 2012), this is taken further in an effort to specify the different forms of knowledge practices in which the students take part. Here, the authors distinguish between practices such as analyzing, evaluating, applying, and creating.[2] Through these terms, the epistemic practices and strategies that constitute expertise are brought to attention. The data utilized in this study did not allow the authors to look into disciplinary differences; however, this is mentioned as an important issue if we want to understand more about what research experiences and inquiry-based learning offer students of different programs.

Zimbardi and Myatt (iFirst 2012) presented another categorization in a study in which they conducted interviews targeting 68 undergraduate research programs across 26 discipline-based schools at a large Australian university. The aim was to investigate the variety of ways in which research experiences were embedded in undergraduate curricula. The distinction used by these researchers concerns the type of projects the students are involved in, conceptualized as apprenticeship projects (students work under the direct supervision of an academic staff member), industry projects (students focus on complex problems from real work situations), inquiry projects (students undertake the entire research process as a way of learning disciplinary content and processes of knowledge production), and methods courses.

Levy and Petrulis (2012) made a similar distinction in their study of research experiences among first-year students in arts, humanities, and social sciences at a UK university. As a starting point, they distinguished between research as a matter of gathering information, research as exploring others' ideas, research as evidencing and developing students' own ideas, and

[2] In Spronken-Smith's description, these practices are conceptualized as forms of learning and also include, in addition to the types listed here, memorizing, understanding, and reflecting.

research as making discoveries. They found that the two latter categories provided a deeper sense of participating in knowledge building, which stimulated intellectual as well as personal development. This form of more "open ended" engagement also seemed to foster identification with the students' academic or professional discipline (ibid.). The results were used to refine a suggested conceptual framework for inquiry-based learning, which distinguishes between four modes of knowledge engagement—identifying, pursuing, producing, and authoring—and relates them to the epistemic orientation of the activity, the status of the student in the investigative process, and the level of support respectively.

In sum, it seems to be generally acknowledged across domains that research engagement enhances students' development of domain-specific knowledge as well as generic skills. This form of engagement implies taking part in core epistemic practices in the students' respective domain, as a means to produce new knowledge or insights. A general finding across these studies seems to be that students report learning more when involved in their own project and when assuming some responsibilities for the different phases of a research initiative (see also Turner, Wuetherick, and Healey 2008). Moreover, open-ended explorations or problem solving seems to serve a "binding role" (Jensen and Lahn 2005) through which students create affective connections with their expert communities.

At the same time, differences are identified between disciplinary communities when it comes to when and how students should be engaged and regarded as contributors to research (Robertson and Bond 2005), as well as what it means to participate in proper ways (Brint *et al.* 2012). Research based on the University of California Undergraduate Experience Survey indicates that students in the "hard" disciplines in the STEM domains more often assist faculty in research, while students in the "soft" disciplines in, for example, arts and humanities and social sciences seem to be more involved in research that gives course credits (Brint *et al.* 2010). Moreover, the ways that knowledge is generally understood and structured within disciplines seem to generate distinct epistemologies among academics, which in turn influence ideas about research-based teaching and learning (Robertson 2007). Accounting for these differences as well as for the distinct knowledge processes that constitute expert domains is important. As pointed out by several researchers (Brint *et al.* 2008, Jones 2009) scientific literacy and epistemic fluency is not generic, as sometimes assumed by current educational policies, but rather highly domain-specific.

While it is often assumed that laboratory work and assisting faculty in research provide students with rich experiences, such forms of engagement may also imply that students get access to delimited parts of the research process. One example of the latter is described by Bhattacharyya (2008), who studied the epistemic development of students in organic chemistry. A student who assisted faculty in a lab environment was asked why he did not employ theoretical concepts and models from his various courses to understand the processes taking place in the lab. His answer was, "I just don't do it because it's more what my advisor thinks the results mean and where the advisor thinks the results go" (p. 89). Apparently, the task of the student was restricted to monitoring processes and reading off results, which were then passed on to his supervisor for interpretation. This indicates that laboratory experiences are not necessarily rich research experiences and points to the importance of engaging students in the process more fully to develop competencies in core epistemic practices and learn the heuristics of their field.

To get deeper into these issues and explore how different forms of activities offer distinct opportunities for learning, several researchers call for more variegated methodological approaches and for mixed-methods approaches that can address student participation and engagement at different levels. For instance, Levy and Petrulis (iFirst 2012, p. 99) suggest that one adventure for further research is "situated studies of students' understandings and experiences in context." Or, as proposed by Mick Healey (2005, p. 77), one could imagine a wider research program around the issues that address different aspects of the problem complex:

"More systematic research is needed into the disciplinary differences (and similarities) in the way linkages [between research and teaching] are and can be constructed. Some of these studies should be comparative; others should involve detailed case studies within specific disciplines. Identifying the variation in practice within disciplines is just as important as analyzing the differences between disciplines. Exploring and developing the disciplinary spaces in which research and teaching may be linked should be a priority."

One question in this regard is where researchers may turn to find the analytical resources for investigating these questions. In the next section, I will suggest that one opportunity is to bring in concepts and resources from the social studies of science (SSS).

ANALYTICAL RESOURCES FROM SSS: EPISTEMIC PRACTICES AND OBJECT RELATIONS

A main source of inspiration for this part of the discussion is the work of sociologist Karin Knorr Cetina (1999, 2001), and especially her perspectives on epistemic cultures and objects. By using the term "epistemic cultures," Knorr Cetina draws attention to the logics and arrangements through which knowledge comes into being and is circulated, approached, and collectively recognized within science and other expert communities. These logics and arrangements comprise tools, artifacts, and institutional arrangements, but also the specific strategies, visions, and procedures that constitute collective actions and form the "machinery of knowledge construction," which, in a given area of expertise, "make up how we know

what we know" (Knorr Cetina 1999, p. 1). In one sense, her approach resembles the work on the cultures of disciplines (Biglan 1973; Becher and Trowler 2001) that has been influential in higher education research. By focusing more explicitly on the practices through which knowledge is produced and circulated, however, Knorr Cetina provides a dynamic framework that allows for investigating the very practices of inquiry in which experts—and students—engage.

A core concept in this regard is epistemic objects. Expert communities are typically object-centered, in the sense that they are oriented toward exploring, developing, and mobilizing knowledge objects (Knorr Cetina 2001). Such objects are, however, not understood as separate, material things. Rather, they may be described as complex amalgams of material and symbolic resources that constitute knowledge around a problem and, through their inherent complexity, activate a set of opportunities when they are approached (Nerland and Jensen 2012). Moreover, epistemic objects are characterized by their unfolding and question-generating character. As Knorr Cetina (2001, p. 181) stated, "Since epistemic objects are always in the process of being materially defined, they continually acquire new properties and change the ones they have." In the context of higher education, epistemic objects could be models for medical treatment, computer programs, legal texts, the human genome, mathematical problems, and complex representations of financial markets. They are created in epistemic cultures and further developed as people in different settings attend to them, explore their complexity, and materialize their potential in local activities.

For students, engagement with epistemic objects may be regarded as an access point to their particular expert culture and its collective ways of knowing (Jensen and Lahn 2005; Nerland and Jensen 2012). Moreover, they may stimulate learning by their ways of generating epistemic practices when they are approached. They typically carry structuring principles for practice, and give some suggestions for how they might be used. At the same time, they may be approached for different purposes in different settings. For instance, in some contexts they are subjected to validation efforts, testing, and types of evidence-making oriented toward closure and (preliminary) fixedness. In other contexts, they form an explorative site where questions and possibilities are opened up in an elaborative manner, and this process may in turn envision new instantiations and possibilities. The dynamic interplay of these processes constitutes research-like processes, which potentially involve students in core epistemic practices of their expert domain.

In recent years, these analytical resources have been used to some extent to investigate knowledge practices and learning in different types of expert work. Ewenstein and Whyte (2009), for instance, employed the concept of epistemic objects to reveal how visual representations in architectural design had an unfolding ontology that displayed incompleteness and were constantly in flux rather than fully formed. The interplay between these epistemic objects and technical, more frozen objects was important in the design process. Similar dynamics have been described in knowledge practices mediated by drawings in engineering (Bechky 2003) and clinical guidelines in nursing (Nerland and Jensen 2012). Knorr Cetina has, in collaboration with colleagues, investigated how objectual practices play out in the work of financial traders (Knorr Cetina and Bruegger 2000) and also explored how even financial information and economic transactions are mobilized and carried out by way of epistemic practices (Knorr Cetina and Preda 2001). Analyses conducted in the Norwegian research project *Professional Learning in a Changing Society* showed how the interplay between professionals and their knowledge objects generate opportunities for learning across space and time (Nerland and Jensen 2010) as well as a commitment to knowledge and a desire to engage in further explorations beyond what is known (Jensen 2007).

In higher education, studies that draw on these analytical resources are scarce; however, some examples do exist. Damsa *et al.* (2010) used the concept of shared epistemic agency to investigate how groups of university students collaboratively created shared knowledge objects in the context of instructional design activities, and showed how this type of agency was constituted and differently articulated in different groups. Hence, the group dynamics and the collective epistemic strategies matter for the students' experience. Jensen and Lahn (2005) showed how nursing students engage with the concept of care as a knowledge object, which incorporate ideas generated through science but, at the same time, present itself as an open-ended object that allows for—and asks for—multiple interpretations and use. They describe how students first find the abstract, de-contextualized world of theory challenging, but that the "back-and-forward looping between theoretical input and practical experience" offered in the educational program seems to involve the students in objectual dynamics and create ties to knowledge over time. Finally, Muukkonen *et al.* (2010) studied knowledge-creative practices around shared epistemic objects in student teams in the context of an undergraduate project management course. Here, students were distributed to geographically dispersed teams and presented with complex problems based on assignments from two customers in working life. The analysis showed how students, although somewhat distressed with the open-ended character of the problem during the process, benefitted from being involved in knowledge creation and inquiry-oriented processes over time. For these activities to be productive in students' learning, however, careful scaffolding of knowledge practices as well as team processes is needed.

To investigate further how students get access to and participate in epistemic practices and through this become inducted in cultures of expertise, it is suggested that more research could benefit from drawing on the analytical resources described above. This will allow for investigating engagement through the different phases of a research or inquiry project, to identify what epistemic processes are involved, how they evolve around epistemic objects, and how the students develop understanding and skills in investigative processes through their participation in these activities. As such activities may span

across course settings and stretch over time, case studies and methodologies that utilize participant observation to follow activities as they unfold seem productive. Moreover, as epistemic objects typically circulate across institutional boundaries in the expert culture, they also provide linkages between higher education activities and the wider knowledge world. Hence, this provides a perspective on educational programs that bridges the research-education divide. In a wider perspective, such analysis may also enhance our understanding of how academic communities are constituted today. As noted by Meyer and Molineux-Hodgson (2009), epistemic communities "work through connectivity, perhaps not so much by connecting people, but by connecting objects and subjects, people and places, production and distribution, individuals and collectives, histories and futures, the virtual and the concrete." To increase our understanding of the formation of expert communities and cultures in today's society, we need to focus research efforts on how these connections are made and remade, and how people come to participate in knowledge cultures that increasingly have global connections and outreach. In this regard, higher education institutions and their knowledge practices stand out as particularly interesting sites of investigation.

CONCLUSION

This paper has discussed how the increased emphasis on mastering knowledge practices and investigative processes in today's society contribute to change conditions for learning, as well as how this is accounted for in research on student learning in higher education. There seems to be a general agreement in the literature about the importance of developing scientific literacy as well as about how this can be enhanced by involving students in research and inquiry-oriented processes. At the same time, there seems to be relatively few studies that focus on the knowledge practices through which students of today become acquainted with the principles for producing and validating knowledge in specific domains and develop expertise. It is suggested that analytical approaches and perspectives from social studies of science may be employed to supplement current research on student learning. Such analyses may account for the epistemic and trans-local dimensions of learning, and allow for an increased understanding of critical dimensions in students' enrolment and participation in expert cultures today.

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