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Indicating Knowledge Development: An Empirical Investigation from the Perspective of Knowledge Maturing

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Abstract. To remain competitive, organizations need to continuously develop their knowledge. While knowledge work is performed similarly in organizations across different sectors, the measurement and assessment of its results currently lacks standardized approaches. This paper sets out to identify indicators that are suitable for making knowledge development transparent to support monitoring of knowledge work. Therefore, a multi-phase mixed methods approach was chosen. In a series of three studies, an activity-focused perspective towards knowledge work was adopted, where knowledge is viewed as passing through a phased maturing process. An initial set of indicators was identified in an ethnographically-informed study and subsequently refined in an online survey. In the interview study, data was collected from 121 European organizations of different sizes, sectors and knowledge-intensity. Feedback from respondents provided evidence for the suitability of items for indicating knowledge maturing and revealed a structure of five factors that were labeled, interpreted and discussed.

Keywords: knowledge, knowledge maturing, indicator, empirical study

1 Introduction

Knowledge is seen as an essential resource for organizations, both from a strategic and operative perspective [1], [2]. In order to remain competitive, organizations need to be able to manage and continuously develop their knowledge [2], [3]. The share of knowledge work performed in organizations and its growing importance have become apparent over the last decades, notably in changes in employees' work processes and practices [4], [5]. Knowledge work can be distinguished from data, service or routine work and is outlined as production and reproduction of information and knowledge involving activities such as generating, interpreting and representing knowledge, as well as expressing, monitoring, translating and networking [6]. Drucker [7] identifies the need to increase the productivity of knowledge work as one of the key challenges for organizations in the 21st century. While knowledge work is performed similarly in different organizational settings [8], the evaluation of its effects on knowledge and its development is still ambiguous and lacks standardized, integrated approaches [9].

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In this paper, knowledge is viewed as being passed through a series of maturing phases. As an intangible asset, knowledge and consequently knowledge maturing are not directly measurable [10], [11]. However, for providing insights into not directly observable phenomena, the utilization of indicators was proven successfully, for example, in managerial accounting where it has supported improving the productivity of manual work [12], [13]. Appropriate indicators for knowledge maturing can facilitate several endeavors, such as: setting targets and obtaining feedback on knowledge management initiatives aimed at enhancing knowledge maturing; assessing the success of such initiatives; securing and justifying funding as well as deriving lessons learnt; and developing benchmarks for future initiatives [14].

This paper addresses the research question: How can knowledge development be assessed? It contributes by proposing, firstly, indicators that are suitable for measuring knowledge maturing in organizations and, secondly, factors represented by indicators for operationalizing the measurement of knowledge maturing. The following section introduces knowledge maturing as a perspective for understanding and analyzing knowledge development. Central concepts of measurement theory are then sketched out as a second strand for empirical work. Subsequently, the development and refinement of indicators in a mixed methods approach of three studies are described. The results are presented and main findings are discussed together with limitations. Finally, the paper concludes with a summary and outlook for further research.

2 Background to Knowledge Maturing and Indicators

Many definitions and classifications of knowledge are discussed in literature on information systems, strategic management and organizational theory [3], [15-17]. Often, knowledge is distinguished from data and information by adding components like experience, judgment, belief, truth or context [10], [16]. This highlights a strong reliance on human actors (e.g., individuals and communities) as knowledge-processing entities [16]. Knowledge can be described as residing in different media, i.e., a person, a social system or an object [15], [18]. Knowledge bound to a *person* represents individual knowledge that has been learnt or discovered and enables the individual to expand his/her knowledge, to apply it to the needs of an organization and to accomplish tasks [16], [19]. Knowledge bound to a *social system* is referred to as collective knowledge which is particularly embodied in organizational rules, procedures and routines [20], [21]. These manifest themselves in processes that involve several actors and are performed within or across organizations, regardless of whether they are formally described and enforced or informally in use without formal institutionalization [15], [22]. Knowledge represented in an *object* is understood as documented knowledge which can be stored and manipulated [16], [23]. Its higher value in comparison to documented information is stressed by the addition of a context which allows its uncoupling from its creator(s) and making it available for re-use [15], [24].

Conducting knowledge manipulation activities is of major importance to the development of knowledge [8], [25]. Such activities can be performed intentionally as a reaction to a gap discovered in available knowledge that is tried to be filled, by ac-

quiring desired knowledge from external sources, selecting it from internal sources or generating it [8], [26]. The development of knowledge has been described, e.g., from the perspective of knowledge building [27], organizational knowledge creation [28] and organizational learning [29]. Thereby, knowledge is often regarded as traversing the individual, group and organizational level while it passes through several phases of development or maturity [25], [26], [29], [30]. In this paper, knowledge development is viewed from the perspective of knowledge maturing [31] which describes the development of knowledge bound to different media as phases advancing from the individual to the group and organizational level. On an individual level, knowledge emerges in form of ideas [32]. This knowledge is restricted to the individual and embedded in the personal context, it is reflected upon in relation to other ideas, and might still be vague [29], [33]. When the individual starts to share the idea, the knowledge enters the group level [29]. In line with Lave and Wenger [34], knowledge maturing views communities as the main connection between the individual and the organizational level. Sharing of knowledge includes processes like socialization and combination [28] as well as activities such as discussing, co-developing and negotiating meaning [35]. Structured documents are created which help to de-subjectify and integrate the knowledge, allow to combine the knowledge and distributing it across the community's boundaries [29], [36]. With increased formality and commitment on the group level, the knowledge enters the organizational level while it reaches more stability, is legitimized and implemented into the organizational infrastructure in form of processes, business rules or standard operating procedures [29], [37], [38].

Indicators are widely employed in the area of managerial accounting, information systems and knowledge management [39], [40]. Indicators are variables that represent the aggregate status or change in status of entities under study (e.g., groups of persons, objects and institutions), and that are essential to report the (change in) status or to understand the conditions of the entities under study [41]. This definition corresponds to a formal view on indicators that is adopted in this paper, and has been established in psychometric theory and in areas of science that investigate phenomena by employing psychological measurement and relying on statistical procedures which borrow central concepts of measurement theory [42-44]. The employment of indicators for measuring not directly observable factors is described by *operational measurement theory* which defines the measurement of a scientific concept in terms of the procedures and operations used to identify it [44], [45]. Typically more than one indicator is viewed as depending on or causing the factor [42], [44]. However, factors can also be specified on a more abstract level as second-order factors that are operationalized by several first-order factors [46], [47]. Factor models with more than two layers are very rarely examined in research [47] and are beyond the scope of this paper. The measurement of indicators themselves, in contrast, is described by *representational measurement theory* [43], [48]. This theory defines measurement as the assignment of symbols to attributes of entities under study according to rules in order to (a) represent quantities of attributes numerically, or (b) classify the entities with respect to the attribute [42], [49]. Representational measurement theory is especially concerned with the mapping of numerals to attributes of entities [50]. Depending on the admissible basic empirical operations (i.e., determination of equality, of greater or less, of equali-

ty of intervals or differences, and of equality of ratios) which are limited on the one hand by the nature of the entities' attributes and on the other hand by the choice of observation procedures, a nominal, ordinal, interval or ration scale is erected [49].

3 Development and Refinement of Indicators

The 'interview study' that this paper draws on formed the final of a series of three studies which combined qualitative and quantitative elements in a multi-phase mixed methods approach [51] and were performed in the European integrating project MATURE (knowledge-maturing.com). The interview study is founded on the results of an 'ethnographically-informed study' and an 'online survey' which are succinctly outlined in the following. Subsequently, the design of the interview study is described in more detail.

During the *ethnographically-informed study*, knowledge work in seven organizations located in four European countries was investigated by six teams of 18 researchers in total who participated in the daily work lives of 31 employees. During a pilot study, the knowledge maturing phase model [31] was tested to be appropriate for analyzing different aspects of knowledge development. The model appeared to be a supportive vehicle for descriptions and discussions in interview situations and facilitated creating a common understanding between researchers and participants. Thus, the phase model informed both fieldwork and data analysis. As with all three studies, the ethnographically-informed study focused on activities performed by knowledge workers and followed the recommendation to concentrate on what people do when studying knowledge and knowledge work [52]. A rapid approach to collaborative ethnography was adopted which allowed reducing time spend on conducting field work [53]. In addition to writing detailed field notes, expert interview were conducted. The data was analyzed through a collaborative coding procedure. While a detailed description of the applied method and a presentation of the comprehensive results is beyond the scope of this paper [see, e.g., 54], one major finding is taken up for further development, i.e., a set of 27 indicators representing a wide range of signals for knowledge maturing. Based on the results of this study, the indicators were classified into three dimensions according to the media in which knowledge can reside: twelve indicators related to knowledge represented in digital resources, seven indicators for knowledge bound to people and eight indicators for knowledge bound to processes.

To prepare the initial set of 27 indicators for the interview study, an *online survey* was conducted [see also 55]. The goals of this survey were fourfold: (1) to get a deeper understanding of the suitability of the items for indicating knowledge maturing; (2) to reword items for greater clarity; (3) to condense the set of indicators by eliminating those deemed to fit poorly and (4) to collect additional indicators complementing the current set. An online questionnaire was developed containing one statement for each indicator on which the participants were asked to rate on a 7-point Likert scale whether it is a good indicator for knowledge maturing in their organization. To facilitate the explanation of indicators to a target group of practitioners, the collected data of the ethnographically-informed study was used for selecting and shortly describing one

example for each indicator. In one open question for each dimension, participants were asked to add items that qualify for indicating knowledge maturing in their organization. Together with a short description of knowledge and knowledge maturing, a link to the questionnaire was sent to a group of 61 representatives in 45 organizations of different sizes and sectors. These organizations were chosen because of their previously expressed interest in knowledge maturing by having become associated partners of the project and, thus, qualified as informed participants whose feedback supported enhancing content validity [56]. The questionnaire was completed 14 times which represents a response rate of around 23%. The data collected was qualitatively and quantitatively analyzed by a team of three researchers who took part in the ethnographically-informed study. As a result, five indicators were rephrased, six indicators were added and five indicators were excluded. The refined set consisted of 28 indicators, categorized according to the three media in which knowledge can reside: twelve for digital resources, nine for people and seven for processes.

The set of 28 indicators was included in the *interview study* which aimed to (1) validate the results of the preceding studies and (2) investigate the underlying structure of indicators for operationalizing the measurement of knowledge maturing. Therefore, qualitative and quantitative data was collected from a broad set of organizations located in 13 European countries [see also 55]. The guidelines for conducting structured telephone interviews were evaluated in a pilot study conducted with six selected individuals representing a heterogeneous set of organizations. In addition to the results gained through the ethnographically-informed study and online survey, this pilot study aimed to further enhance content validity [56]. It allowed to test the clarity of the descriptions, questions and items in the interview guidelines and to collect feedback about the practicability of the method as well as about the length and format of the interview. Based on the insights from this pilot study, the procedure and interview guidelines were slightly adjusted. Participants appreciated having had access to the interview guidelines for following the explanations and questions read out to them. This procedure eased communication during the interview. The interview guidelines were translated by native speakers of each target-language and an extended version of the interview guidelines was provided to all interviewers to ensure similar insights into knowledge maturing at all interview sites.

The organizations were selected using two sampling approaches: stratified random sampling and purposive sampling [57]. In stratified random sampling lists of organizations were obtained. In purposive sampling, potential interviewees were contacted because researchers were thought that they would either provide interesting contributions to the understanding of knowledge maturing or could act as key informant helping to establish a contact to a representative of the organization. All respondents needed to have a good overview about knowledge handling in the (part of the) organization they represented. This is why interviewees of the target group needed work experience of at least three years, have been employed in the organization for at least one year and ideally hold an executive position. It was aimed at interviewing people who gained experience and had responsibility in the management of knowledge, innovation, organization, change or in human resources. The sample was stratified based on the number of employees and based on the NACE code for statistical classi-

fication of economic activities in the European Community, following the recommendations of OECD and Eurostat [58], [59]. This allowed a stratification according to size (medium vs. large), sector (industry vs. service) and knowledge-intensity[1] (low vs. high).

Each interview started with demographic questions about the interviewee's position (including the field of work), time with the organization, size of the organization and about the part of the organization he/she feels confident to represent. After having described knowledge and knowledge maturing, the interviewer started a discussion aimed at finding instances of knowledge maturing the interviewee had experienced in his/her organization. In this respect, conducting interviews provided an opportunity for creating a common understanding between interviewer and interviewee of the phases of knowledge maturing by transferring and applying them to the context of the participant's organization. This procedure helped to ensure in-depth and qualified responses and, moreover, provided additional contextual data, i.e., comments on items and reflections on described instances of knowledge maturing. In the second part of the interview, perceptions about the suitability of the 28 items for indicating knowledge maturing in the context of the represented organization were collected on a 7-point Likert scale. Where possible and permitted by interviewees, the interview was recorded and part-transcribed for data analysis later on.

4 Sampling and Indicator Structuring

In sum, 939 organizations were contacted of which 139 (14.8%) participated in interviews of around one hour each. Out of these, 128 cases fulfilled the selection criteria, i.e., the organization was of medium or large size and the interviewee gained sufficient experience both in the current organization and in his/her profession [see also 55]. All 128 cases were subject to a missing data analysis taking into account the 28 variables representing interviewees' perceptions on their suitability for indicating knowledge maturing. Seven cases with at least 50% of missing data were excluded [47]. In the resulting sample of 121 cases none of the 28 variables had more than 4.1% of missing data and no significant patterns were present. Possible outliers were analyzed with univariate and multivariate methods [47]. All five potential outliers were investigated in detail, which included consideration of interviewees' comments, and seemed similar enough to other observations to be retained.

The final sample contains 121 organizations of which approximately two thirds (81; 66.9%) were large and nearly one third (40; 33.1%) was medium-sized. Based on their NACE code, 39 organizations (32.2%) were classified as being part of the industry sector and 74 (61.2%) as being part of the service sector. The majority (78; 64.5%) are classified as highly knowledge-intensive and 35 (28.9%) are less knowledge-intensive. Eight (6.6%) organizations could not be allocated to a specific sector or knowledge-intensity on the basis of NACE codes [59].

[1] Please note: Eurostat [59] refers to knowledge-intensity for the service and technology-intensity for the industry sector. Both will be referred to as knowledge-intensity in this paper.

To investigate respondents' level in the organizational hierarchy and their field of work, data collected on both open questions was evaluated through a coding procedure [51]. The study successfully targeted interviewees who were confident in representing a large part of their organization: nearly half (59; 48.8%) of respondents worked in middle management; 21 (17.4%) were part of senior management; 11 (9.1%) were in charge of projects; 30 (24.8%) did not supervise others. All interviewees had a good understanding of knowledge work performed in their organization. With respect to the field of work, a large part of them (34; 28.1%) were working in human resources; 24 (19.8%) in other business and administration-related areas; 17 (14.1%) in information systems; 15 (12.4%) in change management; 13 (10.7%) in research and development; 10 (8.3%) in knowledge management and innovation; 8 (6.6%) did not specify their field of work.

A high-level structure of indicators is already provided by the classification resulting from the ethnographically-informed study according to representations of knowledge in digital resources, people and processes. For further investigating this structure in order to identify groups of indicators that reflect on knowledge maturing, an exploratory factor analysis was conducted [42], [47]. Similarly to Parasuraman, et al. [60] an iterative approach was applied. The set of all 28 indicators was used as the starting point for an analysis in SPSS 19, where cases were excluded list-wise. The principal component analysis was used as extraction method, oblimin (with Kaiser normalization) as rotation method and eigenvalues greater than 1.0 to determine the number of factors [47], [60]. In a series of factor analyses, items with low loadings on all factors (<.50), items with high cross-loadings and items with low measures of sampling adequacy (<.50) were candidates for elimination [47]. Following this, only items deemed to fit poorly from both a theoretical and statistical point of view were omitted, one per iteration. This sequence of analyses resulted in a final pool of 15 items representing five distinct dimensions (Table 1).

The 15 items show measures of sampling adequacy between .55 and .76. The overall measure of sampling adequacy (.68) is on a mediocre level and above the threshold of .50 for being acceptable [61]. Together with a significant Barlett test of sphericity ($p \leq .001$), these values support the appropriateness of this set of variables for factor analysis [47]. The resulting factor structure supports the classification of indicators according to the three media in which knowledge can reside that resulted from the ethnographically-informed study and was backed by the online survey. In addition to theoretical considerations, the factor solution is supported by a cumulative variance extracted of 61.8% which is above the common threshold of 60% [47]. Applying the iterative factor analyses to the three dimensions individually results in the same factors and provides further evidence for their stability. As a measure for internal consistency and reliability of the elicited factors, coefficient alpha values were calculated [42]. The factors reach values between .61 and .71 (Table 1) which are classified as being on a moderate level [62] and exceed the common threshold of .60 for explorative research [47]. The average inter-item-correlations were calculated as an additional measure to assess internal consistency and reliability of the factors. With values between .35 and .48 they exceed the threshold of .30 classified as exemplary level [62].

Table 1. Descriptive statistics and results of an exploratory factor analysis

Factors and indicators[a]	Descriptive statistics[b]				Loadings[c]				
	n	Mean	Std. dev.	Median	I	II	III	IV	V
Factor I - coefficient alpha = .71, iic = .38									
(1) A DR has been accepted into a restricted domain	119	4,78	1,69	5,0	,81				
(2) A DR was presented to an influential audience	121	5,31	1,66	6,0	,72				
(3) A DR is referred to by another DR	120	5,13	1,44	5,0	,69			-,36	
(4) A DR became part of a collection of similar information	121	4,93	1,45	5,0	,60				
Factor II - coefficient alpha = .67, iic = .40									
(1) A DR was prepared for a meeting	120	4,78	1,45	5,0		,78			
(2) A DR was created by integrating parts of other DR	120	5,15	1,36	6,0		,76			
(3) A DR was created/refined in a meeting	121	5,49	1,27	6,0		,73			
Factor III - coefficient alpha = .62, iic = .35									
(1) A PE has contributed to a project	120	5,46	1,24	6,0			,78		
(2) A PE has contributed to a discussion	121	5,12	1,34	5,0			,72		
(3) A PE changed its role or responsibility	119	4,65	1,57	5,0			,56		
Factor IV - coefficient alpha = .65, iic = .48									
(1) A PE is approached by others for help and advice	121	5,99	1,10	6,0				-,83	
(2) A PE is an author of many documents	121	5,05	1,40	5,0				-,74	
Factor V - coefficient alpha = .61, iic = .35									
(1) A PR was improved with respect to time, cost or quality	120	6,19	1,01	6,0					,83
(2) A PR was certified or standardised according to external standards	120	5,43	1,70	6,0					,71
(3) A PR has been successfully undertaken a number of times	121	5,88	1,11	6,0			,33		,52

(a) DR = digital resource, PE = person, PR = process, iic = average inter-item-correlation

(b) Likert scale values range from 1 (fully disagree) to 7 (fully agree)

(c) Results of an exploratory factor analysis (n=106), loadings between -0.3 and 0.3 are not shown

The identified factors are labeled and interpreted in the following. This was supported by observations made during the ethnographically-informed study, by recorded comments and reflections of interview study participants, and by discussions with other ethnographers and interviewers.

Factor I) *pass*: Knowledge represented in digital resources is allowed to span boundaries. Knowledge maturing is indicated as the knowledge bound to a digital resource is passed from one domain to another. The knowledge is selected for transfer to a targeted domain with an evident level of protection. In case of knowledge maturing indicators (1), (3) and (4), the selection of knowledge bound to a digital resource and the decision for letting it pass is typically made by a representative of the receiving domain and can be viewed as pull-oriented. For indicator (2), the selection is made by the sender who uses the digital resource as a boundary object when aiming to pass the knowledge to an audience with a certain power (e.g., the customer or a steering group), which can be seen as push-oriented. In both cases, the knowledge represented in the digital resource is assessed to be ready or beneficial for embedding it in a certain target domain and, thereby, providing it to a target group of people who had no access to it beforehand.

Factor II) *consolidate*: Knowledge is combined and embedded in digital resources. Maturing of knowledge bound to a digital resource is indicated as the activity of (further) developing it goes along with a thorough reflection, its assessment and refinement, considering several potentially different points of view. In the case of knowledge maturing indicator (1), this activity is performed to create a target-group-specific representation of the knowledge taking into account the point of view of the person preparing the digital resource and the anticipated expectation of the group of

people who will attend the meeting. Indicator (2) represents the selection and reasonable integration of knowledge bound to other digital resources. Indicator (3) is specifically related to documenting a joint reflection or agreement reached. In each of the three cases, the current state of knowledge is frozen in form of a digital resource.

Factor III) *utilize*: Knowledge bound to a person is applied in interactive group settings. Maturing of knowledge bound to the person is indicated as it is deemed to be exploitable and relevant for accomplishing the tasks to be performed. Especially indicators (1) and (2) emphasize contributions to activities performed in group settings that are marked by an intensive and complex interaction between people, i.e., a project and a discussion. Indicator (3) focusses on a change of roles or responsibilities, typically occurring alongside a change of tasks and people to contact or work with. In all three cases, the person not only contributes with own knowledge but in parallel also gains experience through the knowledge application, receives feedback and further develops own knowledge. Hence, both the knowledge of the individual and of the group is further developed.

Factor IV) *distribute*: Knowledge bound to a person is spread to numerous recipients. Maturing of knowledge bound to that person is indicated because it is repeatedly prepared for sharing with a target group. Furthermore, the person distributing his/her knowledge is perceived to be on a higher skill level than the recipients (with respect to the knowledge distributed). Indicator (1) is related to ad-hoc training sessions the person is involved in, triggered by requests for knowledge held by this person. Indicator (2) emphasizes the creation of structured documents which accompanies the preparation and de-contextualization of knowledge in order to facilitate the take-up by recipients. In both cases, the knowledge bound to the person distributing it is decontextualized, mirrored from the perspective of another context and reflected upon in the light of potential needs of a specific target group.

Factor V) *stabilize*: Knowledge represented in a process reaches a stable state. Maturing of knowledge bound to the process is indicated because of activities that lead to the current state. In the case of indicator (1) these activities are related to improvements which result in a state of perceived enhancement. Indicator (2) covers the successful compliance with requirements of rules or standards external to the organization like ISO 9000 or Basel II. Indicator (3) emphasizes a recurring successful execution of the process evidenced by collective learning and a recurring commitment made by the people performing the process. In case of all three indicators of this factor, evidence is provided that the knowledge bound to the process is legitimized, stable and agreed among the people involved.

A high level of agreement on the 7-point Likert scale can be observed for all indicators representing the five factors (Table 1). Medians of 5 to 6 show that at least 50% of participants agreed that the respective item is a good indicator for knowledge maturing in their organization. To compare the factors with each other, summated scales were created by averaging the ratings of the corresponding items [47] and ten t-tests for two dependent samples [63] were performed (Table 2). *Stabilize* was rated significantly higher than *distribute*. Both *stabilize* and *distribute* were rated significantly higher than *consolidate, utilize* and *pass*. No significant difference was calculated between the ratings for *consolidate, utilize* and *pass*.

Table 2. Differences between factors

	Pass	Consolidate	Utilize	Distribute	Stabilize
Pass	5.05	.419	.815	.000	.000
Consolidate	.102	5.15	.488	.004	.000
Utilize	.029	.073	5.08	.000	.000
Distribute	.474	.372	.445	5.52	.004
Stabilize	.791	.689	.762	.317	5.84

Note: The diagonal contains mean values; levels of significance are above the diagonal; absolute differences between mean values are below the diagonal; df=120 for each test.

5 Discussion and Limitations

The high levels of agreement of interviewees representing 121 organizations provide strong support for the suitability of indicators for measuring knowledge maturing. An iterative factor analysis revealed an underlying structure of five factors which supports the distinction between maturing of knowledge bound to different media. For knowledge represented in digital resources and knowledge bound to people, two factors are suggested each. For both dimensions, the factors build an intermediate layer between the high-level dimensions and the indicators. Viewed from the perspective of operational measurement theory, they can be seen as first-order factors, whereas the dimensions of knowledge bound to digital resources and people would qualify as second-order factors [44], [45].

The five factors show high mean levels of agreement (Table 2). In comparison to other factors, the significant higher agreement to *stabilize* emphasizes the relevance of knowledge bound to processes which is highlighted for example by Davenport and Prusak [10], and according to interviewees, is also important for indicating knowledge maturing. The significantly higher mean levels of agreement to *distribute* knowledge bound to people and *stabilize* knowledge bound to processes – in comparison to *pass* and *consolidate* knowledge represented in digital resources – not only show that knowledge maturing is perceived as strongly intertwined with (structured) interactions of people but also resonates with the strong dependency of knowledge on human actors [8], [16].

The five factors show an activity-related perspective on knowledge maturing as each factor is concerned with knowledge manipulation activities [8]. Following the high agreement to the factors, performing such activities is assumed to be one aspect of indicating knowledge maturing. This echoes the recommendation to measure knowledge indirectly and activity-related [64], which also seems to hold true for measuring knowledge maturing. From an activity perspective, some factors are closer related to each other than others. For example, *pass* and *distribute* are both related to a form of sharing knowledge. However, from another aspect of indicating knowledge maturing – the aspect of the media in which the assessed knowledge resides, they differ. A third aspect of indicating knowledge maturing considered by the factors is the actors' perceptions of the knowledge. This resonates well with the proposal to concentrate on interactions between the 'knower' and representations of knowledge when performing measurement on knowledge [11]. The knower pays attention and allocates time to perform activities on representations of knowledge only if he/she

perceives the knowledge to be valuable [11] (e.g., for a target group or for accomplishing a specific task), which also seems indicative for knowledge maturing that has taken place. Following that, observing the actors' perceptions of the knowledge is important when measuring knowledge maturing. For assessing knowledge represented in digital resources, e.g., in the case of *pass* the perceptions of individuals (on the sending or receiving side) are decisive. For assessing knowledge bound to people, e.g., in the case of *utilize* the perceptions of relevance and applicability of the individual's knowledge are crucial. For assessing knowledge bound to processes in the case of *stabilize*, e.g., the perceptions of individuals performing, enhancing or assessing the process are decisive.

Measuring knowledge maturing indicators can help with highlighting knowledge that is currently maturing or has been maturing in the past. As things that are measured get higher attention [12], the process of selecting knowledge maturing indicators (and combinations thereof) is an important task. The factors can provide support for selecting indicators, e.g., for assessing knowledge management initiatives that aim at the support of selected knowledge manipulation activities. The media in which knowledge resides can guide the selection of indicators with respect to the knowledge management strategy [65]. When focusing on codification, managers can emphasize factors and indicators related to knowledge bound to digital resources and use the others in a supporting role. If personalization is focused, indicators and factors related to knowledge bound to people can be stressed and the others can support.

Although this work uses well-established research methods, a few limitations have to be acknowledged. Firstly, the concept under study, i.e., knowledge maturing is complex. Because of this, much effort has been invested in conducting interviews instead of relying solely on questionnaires. Interviewers were carefully selected, and jointly created a common set of definitions, explanations and examples that made the task of creating an appropriate understanding at interviewees' sites easier. Secondly, conducting 139 interviews in different languages was only possible through sharing the effort among a group of researchers which could have resulted in different answers [66]. In order to mitigate this potential effect, the interviewers were strongly involved in the design of the interview guidelines. Moreover, no significant differences between cases of different interviewers were found. Thirdly, only a single respondent represented (a large part of) an organization. However, this is a common practice in business and management surveys [57]. For further compensating potential effects, it was ensured that the interviewees had a good command of knowledge handling in (the part of) the organization they were confident to represent and that they had been with the current organization for some time. Furthermore, confidentiality was assured to all participants. Finally, applying purposeful sampling leads to a limited generalizability of results [57]. However, this is why medium-sized and large organizations were targeted, as they are supposedly more homogeneous in the way they handle knowledge than small organizations. Furthermore, no significant differences were found between different strata. Although conducting telephone interviews limited the sample size, it provided the opportunity to create a shared understanding of complex phenomena between interviewee and interviewer and, thus, enabled the collection of high quality data.

6 Conclusion and Outlook

To increase awareness of productivity of knowledge work in organizations, instruments that support its monitoring are of major importance. The indicators for knowledge maturing presented in this paper can be used to gain feedback on knowledge management initiatives and to enable managers to grasp the effects of such initiatives. While many approaches aimed at assessing knowledge and knowledge work borrow instruments from related disciplines and apply them top-down [9], [67], this paper contributes with indicators that were developed bottom-up by studying knowledge and knowledge work in a series of three studies from the perspective of knowledge maturing. Building upon a set of indicators developed inductively in an ethnographically-informed study, an online survey refined and complemented these indicators. The interview study shows that the indicators are perceived to be well-suited for assessing knowledge maturing from the perspective of 121 organizations. An exploratory factor analysis revealed an underlying structure of indicators. The identified factors were labeled (*pass*, *consolidate*, *utilize*, *distribute* and *stabilize*), interpreted, and discussed from different perspectives. While supporting the classification of indicators according to the three media in which knowledge can reside, the factors suggest an intermediate level of first-order factors, view indicators from the perspective of performed activities, and highlight actors' perceptions of knowledge. Together with the distinction of indicators bound to different media, these factors can guide an organization's selection of indicators which Horngren [68] describes as, step *one:* deciding on high-level groups of indicators, and *two:* choosing indicators for the process of designing a system of indicators. However, step *three:* defining how selected indicators are measured, *four:* setting the target for indicators and *five:* choosing the timing for feedback, all were beyond the scope of this paper. The definition of observable attributes, their representation as indicators on certain scales (e.g., nominal or ratio) and a reassessment of factors based on that as well as the evaluation of indicators and factors with respect to their current value or their time-dependent development could constitute avenues for future work. Information technology that is recognized as supportive for knowledge management [16] can be utilized for measuring knowledge maturing indicators. Continuous software-based measurement of indicators holds potential for obtaining an up-to-date impression of knowledge maturing. The approach and the findings presented in this paper provide insights into the measurement of knowledge maturing and are intended to stimulate researchers' and practitioners' reflections when performing related activities.

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References

1. Grant, R.M.: Toward a Knowledge-Based Theory of the Firm. Strategic Management Journal 17, 109-122 (1996)
2. Zack, M.H., McKeen, J., Singh, S.: Knowledge Management and Organizational Performance: An Exploratory Analysis. Journal of Knowledge Management 13, 392-409 (2009)
3. Swan, J.: Managing Knowledge Work. In: Galliers, R.D., Currie, W.L. (eds.): The Oxford Handbook of Management Information Systems: Critical Perspectives and New Directions, pp. 535-559. Oxford Univ. Press, Oxford (2011)
4. Blackler, F.: Knowledge, Knowledge Work and Organizations: An Overview and Interpretation. Organization Studies 16, 1021-1046 (1995)
5. Wolff, E.N.: The Growth of Information Workers: In the U.S. Economy. Communications of the ACM 48, 37-42 (2005)
6. Schultze, U.: On Knowledge Work. In: Holsapple, C.W. (ed.) Handbook on Knowledge Management, pp. 43-58. Springer, Berlin (2003)
7. Drucker, P.F.: Knowledge-Worker Productivity: The Biggest Challenge. California Management Review 41, 79-94 (1999)
8. Holsapple, C.W., Joshi, K.D.: Knowledge Manipulation Activities: Results of a Delphi Study. Information & Management 39, 477-490 (2002)
9. Passerini, K.: Knowledge-Driven Development Indicators: Still an Eclectic Panorama. Journal of Knowledge Management 11, 115-128 (2007)
10. Davenport, T.H., Prusak, L.: Working Knowledge. How Organizations Manage What They Know. Harvard Business School Press, Boston. (1998)
11. Glazer, R.: Measuring the Knower: Towards a Theory of Knowledge Equity. California Management Review 40, 175-194 (1998)
12. Eccles, R.G.: The Performance Measurement Manifesto. Harvard Business Review 69, 131-137 (1991)
13. Radujković, M., Vukomanović, M., Dunović, I.B.: Application of Key Performance Indicators in South-Eastern European Construction. Journal of Civil Engineering and Management 16, 521-530 (2010)
14. Kankanhalli, A., Tan, B.C.Y.: Knowledge Management Metrics: A Review and Directions for Future Research. International Journal of Knowledge Management 1, 20-32 (2005)
15. Maier, R.: Knowledge Management Systems - Information and Communication Technologies for Knowledge Management. Springer, Berlin (2007)
16. Alavi, M., Leidner, D.E.: Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. MIS Quarterly 25, 107-136 (2001)
17. Palte, R., Hertlein, M., Smolnik, S., Riempp, G.: The Effects of a KM Strategy on KM Performance in Professional Services Firms. International Journal of Knowledge Management 7, 16-34 (2011)
18. McLure Wasko, M., Faraj, S.: "It is What One Does": Why People Participate and Help Others in Electronic Communities of Practice. The Journal of Strategic Information Systems 9, 155-173 (2000)
19. Marr, B., Schiuma, G., Neely, A.: Intellectual Capital – Defining Key Performance Indicators for Organizational Knowledge Assets. Business Process Management Journal 10, 551-569 (2004)
20. March, J.G.: Exploration and Exploitation in Organizational Learning. Organization Science 2, 71-87 (1991)
21. Spender, J.C.: Organizational Knowledge, Collective Practice and Penrose Rents. International Business Review 3, 353-367 (1994)

22. Szulanski, G., Jensen, R.J.: Overcoming Stickiness: An Empirical Investigation of the Role of the Template in the Replication of Organizational Routines. Managerial and Decision Economics 25, 347-363 (2004)
23. McQueen, R.: Four Views of Knowledge and Knowledge Management. In: Americas Conference on Information Systems, 609-611 (1998)
24. Zack, M.H.: Managing Codified Knowledge. Sloan Management Review 40, 45-58 (1999)
25. Bhatt, G., D.: Organizing Knowledge in the Knowledge Development Cycle. Journal of Knowledge Management 4, 15-26 (2000)
26. Allard, S.: Knowledge Creation. In: Holsapple, C.W. (ed.) Handbook on Knowledge Management, pp. 367-379. Springer, Berlin (2004)
27. Cress, U., Kimmerle, J.: A Systemic and Cognitive View on Collaborative Knowledge Building with Wikis. International Journal of Computer-Supported Collaborative Learning 3, 105-122 (2008)
28. Nonaka, I.: A Dynamic Theory of Organizational Knowledge Creation. Organization Science 5, 14-37 (1994)
29. Crossan, M.M., Lane, H.W., White, R.E.: An Organizational Learning Framework: From Intuition to Institution. The Academy of Management Review 24, 522-537 (1999)
30. Choo, C.W.: The Knowing Organization. How Organizations use Information to Construct Meaning, Create Knowledge, and Make Decisions. Oxford Univ. Press, New York (1998)
31. Maier, R., Schmidt, A.: Characterizing Knowledge Maturing: A Conceptual Process Model for Integrating E-Learning and Knowledge Management. In: 4th Conference Professional Knowledge Management, 325-334 (2007)
32. Välikangas, L., Sevón, G.: Of Managers, Ideas and Jesters, and the Role of Information Technology. The Journal of Strategic Information Systems 19, 145-153 (2010)
33. Weick, K.E.: Mundane Poetics: Searching for Wisdom in Organization Studies. Organization Studies 25, 653-668 (2004)
34. Lave, J., Wenger, E.: Situated Learning: Legitimate Peripheral Participation. Cambridge University Press (1991)
35. Davenport, T.H., Jarvenpaa, S.L., Beers, M.C.: Improving Knowledge Work Processes. Sloan Management Review 37, 53-65 (1996)
36. Star, S.L., Griesemer, J.R.: Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. Social Studies of Science 19, 387-420 (1989)
37. Tuomi, I.: Corporate Knowledge - Theory and Practice of Intelligent Organizations. Metaxis, Helsinki (1999)
38. Suchman, M.C.: Managing Legitimacy: Strategic and Institutional Approaches. Academy of Management Review 20, 571-610 (1995)
39. Poston, R.S., Speier, C.: Effective Use of Knowledge Management Systems: A Process Model of Content Ratings and Credibility Indicators. MIS Quarterly 29, 221-244 (2005)
40. Fairchild, A.M.: Knowledge Management Metrics via a Balanced Scorecard Methodology. In: Hawaii International Conference on System Sciences, 243-250 (2002)
41. Jaeger, R.M.: About Educational Indicators: Statistics on the Conditions and Trends in Education. Review of Research in Education 6, 276-315 (1978)
42. Nunnally, J.C., Bernstein, I.H.: Psychometric Theory. McGraw-Hill, New York (1994)
43. Michell, J.: Measurement Scales and Statistics: A Clash of Paradigms. Psychological Bulletin 100, 398-407 (1986)
44. Hand, D.J.: Statistics and the Theory of Measurement. Journal of the Royal Statistical Society. Series A (Statistics in Society) 159, 445-492 (1996)

45. Dingle, H.: A Theory of Measurement. The British Journal for the Philosophy of Science 1, 5-26 (1950)
46. Jarvis, C.B., MacKenzie, S.B., Podsakoff, P.M.: A Critical Review of Construct Indicators and Measurement Model Misspecification in Marketing and Consumer Research. Journal of Consumer Research 30, 199-218 (2003)
47. Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E.: Multivariate Data Analysis. A Global Perspective. Pearson, Upper Saddle River, NJ (2010)
48. Franceschini, F., Galetto, M., Maisano, D.: Management by Measurement. Designing Key Indicators and Performance Measurement Systems. Springer, Berlin (2007)
49. Stevens, S.S.: On the Theory of Scales and Measurement. Science 103, 677-680 (1946)
50. Roberts, F.S.: Measurement Theory with Applications to Decisionmaking, Utility, and the Social Sciences. Addison-Wesley Advanced Book Program, Reading, Mass (1979)
51. Creswell, J.W., Plano Clark, V.L.: Designing and Conducting Mixed Methods Research. SAGE, Los Angeles (2011)
52. Blackler, F., Reed, M., Whitaker, A.: Epilogue - An Agenda for Research. Journal of Management Studies 30, 1017-1020 (1993)
53. Maier, R., Thalmann, S.: Collaborative Ethnography for Information Systems Research - Studying Knowledge Work Practices and Designing Supportive Information Systems. Australasian Journal of Information Systems 17, 137-160 (2012)
54. MATURE D1.1: Results of the Ethnographic Study and Conceptual Knowledge Maturing Model, Kaschig, A., Maier, R., Sandow, A., Schmidt, A., Thalmann, S. (eds.): MATURE Project Deliverable, No. D1.1 (2009)
55. MATURE D1.2: Results of the Representative Study and Refined Conceptual Knowledge Maturing Model, Kaschig, A., Maier, R., Sandow, A., Schmidt, A. (eds.): MATURE Project Deliverable, No. D1.2 (2010)
56. Straub, D.W.: Validating Instruments in MIS Research. MIS Quarterly 13, 147-169 (1989)
57. Bryman, A., Bell, E.: Business Research Methods. Oxford Univ. Press, Oxford (2007)
58. OECD, Eurostat: Oslo Manual - Guidelines for Collecting and Interpreting Innovation Data. OECD Publishing, Paris (2005)
59. Eurostat: 'High-Technology' and 'Knowledge Based Services' Aggregations, http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/Annexes/htec_esms_an3.pdf, (2009)
60. Parasuraman, A., Zeithaml, V.A., Malhotra, A.: E-S-QUAL: A Multiple-Item Scale for Assessing Electronic Service Quality. Journal of Service Research 7, 213-233 (2005)
61. Kaiser, H.F., Rice, J.: Little Jiffy, Mark IV. Educational and Psychological Measurement 34, 111-117 (1974)
62. Robinson, J.P., Shaver, P.R., Wrightsman, L.S.: Criteria for Scale Selection and Evaluation. In: Robinson, J.P., Shaver, P.R., Wrightsman, L.S. (eds.): Measures of Personality and Social Psychological Attitudes, pp. 1-15. Academic Press, San Diego (1991)
63. Sheskin, D.J.: Handbook of Parametric and Nonparametric Statistical Procedures. Chapman & Hall/CRC, Boca Raton, Fla. (2007)
64. Fahey, L., Prusak, L.: The Eleven Deadliest Sins of Knowledge Management. California Management Review 40, 265-276 (1998)
65. Hansen, M.T., Nohria, N., Tierney, T.: What's Your Strategy For Managing Knowledge? Harvard Business Review 77, 106-116 (1999)
66. Groves, R.M.: Survey Errors and Survey Costs. Wiley, Hoboken (2004)
67. Sveiby, K.-E.: Methods for Measuring Intangible Assets, http://www.sveiby.com/articles/IntangibleMethods.htm, (2001, updated 2010)
68. Horngren, C.T.: Management and Cost Accounting. Prentice Hall, Harlow (2002)