Scientific Tacit Knowledge Among Researchers with Long Scientific Seniority: Towards a Four-Pillar Framework

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Abstract: This study addresses the topic of scientific tacit knowledge (STK), specifically related to employees with Long Scientific Seniority (LSS), defined as those with more than 25 years of postdoctoral experience. STK serves as an internal resource for scientific institutions and contributes to high-quality research. Despite its importance, STK remains relatively underexplored in the literature; however, it is considered important in engineering sciences, such as construction. The research question focuses on understanding the characteristics and structure of the STK. An extensive literature review of STK definitions was conducted using multiple databases. An online survey was conducted among fourteen construction-related research institutions in Europe (five research institutes and nine universities) to understand how LSS personnel and their tacit knowledge are perceived within these institutions. Based on the survey findings, 51 in-depth interviews were conducted to gain a better understanding of STK. Participants were divided into three groups: LSS employees, their co-workers, and their leaders. The thematic analysis of the qualitative interview data led to the identification of recurring STK components, which were subsequently organised into four pillars. The cognitive pillar includes research intuition, pattern recognition, knowledge synthesis, and a deep understanding of scientific processes. The practical pillar consists of research skills, technical competence, complex problem-solving, historical knowledge, and academic writing skills. The ethos pillar includes work ethic, emotional engagement, and academic value. The relational pillar refers to academic culture, informal rules and practices, and the expert networks. This study had some limitations. First, it was conducted in scientific institutions within the construction field, and the interview data reflected the participants' perspectives. Further research may include examining different disciplines, such as natural and social sciences, to determine which pillars are more universal and which differ across disciplines.

Keywords: Tacit knowledge management, Long scientific seniority (LSS), Knowledge sharing, Scientific tacit knowledge (STK), Construction academia, Tacit knowledge

1. Introduction

Scientific work is commonly represented by formal outputs such as publications and methods. However, an important part of scientific practice remains difficult to articulate or codify fully. This article addresses the less visible dimension through the concept of scientific tacit knowledge (STK). It aims to provide a more precise and empirically grounded understanding of STK by presenting the four pillars identified in this study and outlining their internal structure.

This study is situated in the context of civil engineering, especially construction science, a field characterised by strong and durable epistemic foundations. Its knowledge base rests on relatively stable principles derived from disciplines such as physics and mathematics, while simultaneously remaining highly formalised, methodologically demanding, and strongly oriented toward correctness, reliability, and long-term consequences (Czarnecki and Van Gemert, 2017).

Three concepts are central to this study. First, long scientific seniority (LSS) is defined as 25 years (or more) after obtaining a PhD, which translates into extensive scientific, research, and expert experience accumulated over time. Scientific knowledge refers to the body of facts and principles known in a given field (He and Zhang, 2009), as well as to the descriptive content of the best available theories and models and the skills and concepts required to understand that content (Chakravartty, 2023). Simultaneously, it adheres to high epistemic standards, seeking to represent the studied reality with accuracy and insight while employing organising frameworks such as classifications and groupings in its descriptions (Zemło, 2022). Tacit knowledge (TK) was defined from the very beginning as "we can know more than we can tell" (Polanyi, 1966). Nonaka and Takeuchi defined it as "personal knowledge embedded in individual experience", involving "intangible factors such as personal belief, perspective, and the value system". Building on these foundations, STK is treated here as the tacit dimension of scientific work: knowledge embedded in scientific and research practice, accumulated scientific and expert experience, and the often-unspoken understanding of how to produce, assess, interpret, and develop scientific knowledge responsibly and effectively.

This study addresses two main questions: What is STK, and what are its defining features and internal structure? These questions are particularly important in construction, where research quality depends not only on explicit knowledge but also on interpretive competence, and the ability to synthesise complex evidence. The importance of STK lies in its contribution to a deeper understanding of scientific processes, interpretation of research results, and synthesis of knowledge developed over time. It also contributes to innovation by helping researchers build on prior scientific work rather than approaching problems in isolation.

The empirical basis of this article is qualitative research conducted in scientific institutions in Poland and other European countries. The study draws on survey data and in-depth interviews to identify recurring patterns in how STK is understood and enacted in scientific practice, providing the basis for distinguishing the four pillars of STK and discussing their characteristics.

This study contributes to the literature by expanding the understanding of STK as a distinct and internally differentiated component of scientific work. A clearer conceptualisation of this form of knowledge may support its accurate recognition, documentation, sharing, and use in scientific institutions.

2. Literature Review

Scientific tacit knowledge is not a commonly used term in the literature. A search for this term in the Scopus database yielded two titles, while a search in the WoS database yielded one title that matched the one found in Scopus. Owing to the small number of results, the search was extended to additional sources, including Google Scholar and Semantic Scholar.

As early as the 1970s, researchers were becoming increasingly convinced that TK plays an important role in science, although analyses of its role in shaping scientific results and conclusions were still relatively rare (Soler and Zwart, 2013). Collins (1974) argued that even highly formalised knowledge contains tacit rules that cannot be fully articulated, and that learning in science is therefore not reducible to the transfer of explicit information.

This view was further developed in subsequent studies.

Travis (1995) approached science as a practice, emphasising both experimental skills and the production of knowledge, artefacts, and effects. In this view, TK is a key practical resource that shapes how scientists set up apparatus and solve problems. Cambrosio and Keating (1988) also noticed the tacit dimensions of scientific work, later described by Pozzali (2008) as cognitive and non-physical.

Leite (2007) defines STK as knowledge “which relates to a researcher’s skills, experiences and competencies, is employed in the conduct of their scientific activities, and is difficult to communicate formally”. Horikawa (2010) states that STK encompasses elements such as the empirical interpretation of phenomena, knowledge of how to use scientific tools, and the interpretation of measurement accuracy. Albuquerque et al. (2017) indicate that STK is located in the expert’s mind and includes what specialists know and have learned, but what is not captured in the structured databases.

The growing practical relevance of this issue can also be seen in recent initiatives aimed at identifying and externalising tacit knowledge in scientific work. In 2025, the “BioSkillDX” project was launched in Japan to visualise and digitise tacit knowledge, such as advanced skills, know-how, and tips required in life science laboratories, using artificial intelligence (AI), and developing a new operational support platform that will enable anyone to reproduce experiments with high accuracy.

Insch et al. (2008) described Academic Tacit Knowledge (ATK) and proposed a multidimensional structure of TK, which includes cognitive skills, technical skills, and social skills.

3. Methods

3.1 Research Design

This study adopted a qualitative research design. The methodological framework combined three elements: a focused review and critical analysis of the literature, an online survey, and in-depth interviews. The study drew on methodological triangulation (Denzin, 1978) by combining survey data with qualitative interview material and theoretical triangulation by confronting the empirical findings with insights from the literature on TK and its scientific dimension.

The online survey was conducted between March 2024 and November 2024. In-depth interviews were conducted between April 2024 and March 2025. The survey served as the exploratory stage of the study, while the interviews were used to deepen and contextualise the emerging findings.

3.2 Sample Selection

The research was conducted across 14 scientific institutions, including six in Poland (PL) and eight in other European countries (oEU). The institutional sample comprised five research institutes — two from Poland and three from EU — and nine construction faculties of polytechnics/universities — four from Poland and five from EU.

A purposive, non-random sampling strategy was adopted to include participants representing different perspectives on LSS and its role in scientific institutions. The sample included three groups of respondents: 16 LSS individuals, nine individuals serving as LSS leaders, L-LSS, and 27 individuals cooperating with LSS, C-LSS.

The study included 52 online survey responses and 51 in-depth interviews.

3.3 The Online Survey Protocol

The online survey was prepared in Polish and English and administered using the StartQuestion platform. The questionnaire consisted of 94 statements grouped into five thematic areas.

1. Awareness of tacit knowledge,
2. Personal motivation to share or not to share the TK of LSS persons,
3. Traditional versus innovative approaches,
4. Organisational support for knowledge sharing,
5. Generational diversity management.

Respondents were asked to assess the statements using a five-point Likert scale, where 1 indicated strongly disagree and 5 indicated strongly agree. The survey was anonymous, and no time limit was imposed. Because the study involved three respondent groups, the questions in the first two thematic areas were adapted to suit the role of the respondent. The remaining three areas were identical across all the groups. At the end of the questionnaire, respondents were given space for additional comments, followed by demographic or role-related items relevant to each group of respondents.

To facilitate participation and reflection, the questionnaire was distributed in PDF format one week before the survey link was sent. The main purpose of the survey was to explore how LSS persons and their scientific knowledge are perceived in the construction academia environment. The survey findings were subsequently used to inform the design of the interview protocols.

3.4 The In-depth Interview Protocol

The in-depth interview protocol was prepared in Polish and English and consisted of a glossary of key terms and 17 open-ended questions, as follows: two versions of the interview guide were developed: one for LSS participants and one for leaders and co-workers of LSS persons. Each participant received the relevant interview guide approximately one week before the interview.

Most interviews were conducted in person; however, online interviews were used when needed. The maximum planned duration of a single interview was 2.5 h.

The main purpose of the interviews was to deepen understanding of the scientific knowledge held by LSS individuals and examine its role, meaning, and practical significance within scientific institutions.

3.5 Data Analysis

The survey stage was treated as a qualitative and exploratory component of this study. It was intended to support the most comprehensive possible understanding of the phenomenon under investigation, namely, the STK of LSS individuals (Krok, 2015; Braun et al., 2020). Likert-scale responses were analysed qualitatively, with particular attention to patterns of internal consistency within each respondent group (LSS, C-LSS, and L-LSS) across the five thematic areas. Group differences were also examined within the Polish sample and within the sample drawn from oEU, followed by a comparative reading of the patterns observed across these two contexts.

The interview material was transcribed and analysed through a staged coding procedure, following Saldaña (2009). This process involved pre-coding, holistic coding aimed at synthesising the material, and structural coding to relate the responses to the research questions. This analytical procedure made it possible to identify recurring patterns in the understanding, description, and manifestation of STK in scientific practice.

4. Results

4.1 The Research Sample Structure

The results are presented by respondent group and language version of the study, allowing comparison between LSS persons, their leaders, and co-workers, as well as between Polish- and English-speaking participants. To support the interpretation of group differences, the structure of the sample is briefly outlined below.

Table 1 shows the breakdown of the study group by institution and the languages used in the questionnaire and interviews. The Polish-speaking group consisted of 32 respondents, the and English-speaking group consisted of 20 respondents. The smallest group of respondents consisted of those representing research institutes based outside Poland. Furthermore, there is a clear difference in the number of respondents in the group of LSS supervisors at scientific institutions outside Poland.

Table 1: Structure of the participants

	Poland (Polish)		oEU (English)	
	Research Institute	University	Research Institute	University
LSS	4	5	2	5
LSS' leader	4	3	1	1
LSS' co-worker	8	9	3	7
	16	**17**	**6**	**13**

Table 2: Study participants by gender and researcher status across research groups

	Male	Female	Working as a scientist	n=52
EN LSS	3	4	7	**7**
EN LSS' leader	0	2	1	**2**
EN LSS' co-worker	8	3	9	**11**
PL LSS	7	2	9	**9**
PL LSS' leader	5	2	7	**7**
PL LSS' co-worker	10	6	13	**16**

As shown in Table 2, the respondents were mainly male (33 out of 52 participants), which is not surprising in civil engineering. Only six of the 52 participants were not working as scientists in the institution, which is in line with the topic of the research. There were also clear differences between the groups based in Poland and oEU in terms of the length of employment at their current research institutions. In Poland, 20 out of 32 respondents worked for their current institution for more than 20 years, whereas in oEU, only eight out of 20 respondents worked for their current institution for more than 20 years. However, outside Poland, seven out of 20 people worked for less than five years in the institution, whereas in Poland, only two out of 32 people did.

Table 3: Distribution of study participants by birth-year range and country/region

	Poland (Polish)	oEU (English)
1927-1945	4	0
1946-1964	7	8
1965-1979	16	3
1980-1994	5	8
1995-2010	0	1

It is also worth noting the different distributions of age cohorts, as shown in Table 3. Especially, that only in Poland, four people belonged to the so-called Silent Generation (1927-1945), and only one person from oEU belonged to Gen-Z (1995-2010).

As presented, the sample structure was not fully symmetrical across groups, particularly in terms of group size, gender distribution, and current involvement in scientific work; therefore, the results should be interpreted primarily as qualitative patterns rather than as directly comparable proportions across all categories.

4.2 Online Survey Results

A total of 52 completed questionnaires from 14 scientific institutions were obtained, including 33 from Poland and 19 from oEU. Across the sample, there was broad agreement that LSS persons are recognised as authorities and experts in the field of construction, and that their TK, experience, and unique skills are important for both current scientific work and the development of younger generations. A slightly different pattern appeared among the co-workers of LSS persons from oEU, where "I do not know" responses were more frequent.

The main differences between the respondent groups were observed in Area I, concerning awareness of tacit knowledge, and Area II, concerning personal motivation to share or not to share the TK of LSS persons. These themes were subsequently explored in greater depth during the interviews. In contrast, the responses were more consistent across the Polish sample and the sample from oEU in Areas III (traditional versus innovative approach), IV (organisational support for knowledge sharing), and V (managing generational diversity).

4.3 In-depth Interview Findings

4.3.1 Results from interviews with LSS persons

Interviews with LSS participants (n=15) indicated that an important background to their STK lay in the different conditions under which the knowledge was acquired and consolidated over time. Across both Polish and English-language interviews, respondents described scientific learning as more effort-intensive and focused than today, shaped less by instant access and more by physical library resources, limited specialist literature, and the effort needed to obtain, read, and synthesise books and articles.

Respondents also stressed that earlier educational models focused more on fundamental disciplines and understanding phenomena rather than relying on ready-made outputs, reflected in „having a deep basis for knowledge to understand how things are connected" (EN-DSN-005). Years of practice further shaped this background, as LSS participants faced diverse scientific, expert, and organisational problems and developed their own judgment. While Polish interviews highlighted differences in upbringing, the English-language interviews emphasised diverse experiences, especially international academic exposure and cooperation with industry.

Across all LSS interviews, respondents stressed importance of critical thinking, reflection, dealing with failure, and making sound judgments. Polish interviews more often referred to intuition as an observational sensitivity, the use of metaphors and going beyond routine solutions. English-language interviews emphasised science as a holistic, time-dependent, open-ended process of searching, exploring, and experimenting, reflected in "time to ferment the ideas" (EN-DSN-002), and "Research is not the facts, it's searching, exploring, experimenting" (EN-DSN-005).

In more practical terms, the participants also stressed a highly developed research craft and familiarity with older literature, such as "especially classical papers not available online – very fundamental old papers" (EN-DSN-003). Many respondents also referred to the use of established procedures in their own scientific work, such as having a research strategy (EN-DSN-004), planning publications on an annual basis (PL-DSN-006), or developing their own methods of proceeding in research practice.

4.3.2 Results from interviews with LSS's co-workers

Co-workers of LSS participants (n=27) emphasised the practical dimension of STK. Strong emphasis was placed on the historical perspective, that is, knowledge of what had already been done, attempted, and achieved. Respondents also included ways of proceeding in specific situations (work organisation, building one's own research craft, writing scientific publications). Problem solving was emphasised, as LSS persons were described as capable of "finding different solutions to the same problems" and showing "flexibility in solving problems" (EN-wDSN-006).

Polish respondents additionally stressed practical aspects of expert activity, preparation of formal documents, and "a clear and concise presentation of the problem and the ways to address it" (PL-wDSN-006). English-language respondents emphasised that if a person gets stuck and turns to an LSS person for advice, they will always receive support, either direct advice, an indication of where to look, or guidance on whom to ask (EN-wDSN-003).

Across all interviews, respondents also underlined the importance of the social role played by LSS persons in introducing younger researchers to the academic world, explaining conventions and informal rules, and passing on practical knowledge about how scientific life functions, including the organisation of conferences and academic events.

English-language respondents stressed that LSS persons have very good fundamental knowledge, are capable of seeing long-term trends, and are "not focusing just on one part of the problem but seeing across everything" (EN-wDSN-008). Polish respondents pointed to "a well-developed critical mindset, to avoid jumping to conclusions" (PL-wDSN-006), as well as to the analysis and synthesis of knowledge from various fields. All respondents also drew attention to the networks of LSS persons, often describing how they introduced younger researchers to relevant people to initiate cooperation.

When describing LSS persons, many respondents used nouns like "Personality", "mentor", "authority", and adjectives like "humble" and "modest". Polish group stressed that LSS individuals approached the matters in question with the appropriate level of commitment and showed an interest in the work of young scientists on a day-to-day basis. English group noticed that LSS persons always found the time to answer the young researchers' questions.

4.3.3 Results from interviews with LSS's leaders

Leaders of LSS participants (n=9) described STK as experience-based, context-embedded, and difficult to transfer or codify. In their accounts, STK was associated also with a certain depth and life wisdom that supports sound judgment. It was also linked to the ability to synthesise results and formulate conclusions.

As one respondent observed, as an LSS person, "You are quite sure about your place in the academic context, and you are quite grounded in academic values […] you represent academic values, they are intrinsic to you" – that is why they can guide others. Therefore, they do not have to take on the role of a mentor because they simply become one. (EN-sDSN-001).

In practical terms, leaders emphasised the ability of LSS persons to design and conduct research, solve problems, and possess skills such as writing publications. Polish respondents particularly stressed that LSS persons offer "reliable, purposeful advice", while English-language interviewees more often highlighted the matter of "what's the representation of good research, how do we do that, what's high quality" (EN-sDSN-001).

English-language respondents pointed to the role of LSS persons in preserving and transmitting academic values, including "guarding also the openness in academia, the seminar culture, the curiosity, and guiding that kind of values, and guarding the kind of values and also guiding new persons into the culture" (EN-sDSN-001). Polish respondents, in turn, more often emphasised the broad scientific networks of LSS individuals and the importance of those connections in navigating academic life and supporting research development.

5. Synthesis of Findings and Discussion

The comparison of interview findings across the three respondent groups led to the identification of recurring themes of STK, which were subsequently organised into four interrelated pillars: cognitive, practical, ethos, and relational, as presented in Table 4.

Table 4: The four pillars of STK

STK Pillar	Main keywords from interviews	Main components	Manifesting examples
Cognitive	judgement; intuition; fundamental knowledge; critical mindset; knowledge synthesis;	pattern recognition; knowledge synthesis; deep understanding of scientific processes; insight; intuition;	recognising patterns in data; critically interpreting results; identifying relevant questions;
Practical	research craft; older literature; historical perspective; best practices; problem solving; research design; writing publications;	research design; unique technical skills; academic writing; expert problem-solving; practical use of historical knowledge;	designing experiments; planning research procedures; solving unusual scientific or expert problems;
Ethos	academic values; seminar culture; commitment; authority;	strong work ethic; sense of responsibility; academic values; emotional commitment to scientific work;	meticulousness; responsibility for research quality; constructive criticism;
Relational	introduction to academia; conventions and informal rules; scientific networks;	academic networks; guidance and mentoring; participation in seminars and conferences;	introduction into academic life; helping navigate the scientific environment;

The findings support the view, present in earlier studies, that scientific work cannot be reduced to explicit procedures, written outputs, or formalised instructions, as shown by Collins (1974), Travis (1995), and Cambrosio and Keating (1988). The study shows that scientific work depends also on judgment, interpretation, intuition, historical awareness, and context-sensitive practice. Simultaneously, this study shows that STK is not a single, undifferentiated resource. The four pillars identified here — cognitive, practical, ethos, and relational — indicate that STK includes ways of understanding, acting, and functioning within the scientific community, while also being shaped by internalised academic values. This broadens earlier definitions, such as Leite's (2007), Horikawa's (2010) and Albuquerque et al. (2017).

The cognitive pillar encompasses the mental abilities required to create, interpret, and integrate scientific knowledge. It underpins scientific judgment, understanding complex phenomena, and generating innovation. This pillar supports Pozzali's (2008) argument that tacit knowledge in science may be cognitive and non-physical in nature, and is in line with the cognitive dimension of TK as presented by Insch et al. (2008).

The practical pillar concerns scientific craft, research methodology, and the ability to carry out research and expert work effectively. It supports problem-solving and the maintenance of research quality in both scientific and expert practices. This pillar supports Travis's (1995) understanding of science as practice and aligns with Collins's (1974) emphasis on the limited transferability of many scientific skills through written means alone and with Insch et al.'s (2008) technical dimension of TK.

The ethos pillar encompasses the researcher's values, attitudes, and inner commitment that give meaning to academic work and shape the approach to and practice of science. This reflects the academic ethos embodied by the LSS persons and expressed in their work ethic. Nevertheless, it should be noted that academic ethos itself should not be treated as TK, as it forms part of academic culture, for example, in Merton's (1942) classic framework. However, research findings indicate that academic values and norms are intertwined with STK, manifesting themselves in behaviour and embodying these values.

The relational pillar refers to the interpersonal and community-based dimensions of scientific work through which tacit knowledge is shared and activated in practice. It concerns functioning within the scientific community and gaining orientation in its formal and informal rules of conduct. This pillar supports the social dimension of TK as presented by Insch et al. (2008) and is in line with the earlier work, especially Collins's (1974) view on the role of personal contact in the transmission of TK in the sciences.

6. Conclusions

The study indicates that STK among LSS researchers in construction academia is internally differentiated, with four interrelated pillars — cognitive, practical, ethos, and relational — helping to classify and organise its different types.

The main contribution of this study is the proposal of a more differentiated conceptualisation of STK within construction sciences. The proposed four-pillar framework can be considered a reference point for further research in other academic disciplines, with a particular focus on determining which of the proposed pillars are relatively universal to academic work, and which depend on the specific discipline and the nature of knowledge within that field. For example, differences may arise between the natural sciences and the humanities, as well as in the case of the arts.

Practical implications for research institutions can be presented in three areas: sharing, documenting and disseminating STK. The latter two areas, due to the nature of tacit knowledge, will not be equally effective across all pillars. Still, it is of interest to document and share research related best practices, historical perspective, and informal rules of conduct, to name a few. Sharing STK requires daily, close collaboration between young scientists and LSS persons. This can be supported by creating conditions for close collaboration, organizing problem-oriented seminars, recognising and appreciating mentoring provided by LSS persons.

7. Limitation and Future Research

This study had some limitations. First, it was conducted within construction-related sciences, a field grounded in relatively stable foundations derived from disciplines such as physics and mathematics, where scientific development is strongly cumulative and closely linked to enduring underlying principles. Therefore, the role and structure of STK identified here may differ from those found in disciplines in which scientific development is shaped less cumulatively and linearly by stable underlying principles. Second, the research was conducted in Europe, which means that the findings are embedded in a specific regional and institutional context. Other national settings, academic cultures, and organisational conditions may produce different STK manifestations and structures. Third, the study is based mainly on the interview data. This means that the findings are shaped by the perspectives and interpretations of the respondents, and therefore reflect how STK is understood and described. Fourth, this study was qualitative in nature and based on purposive sample selection. It aimed to gain an in-depth understanding of STK rather than provide a statistically representative picture of the phenomenon itself.

Further studies could include scientific institutions outside Europe to help determine the extent to which the role and structure of STK are shaped by national, organisational, and academic contexts.

Another direction is to investigate the extent to which generative artificial intelligence and advanced digital tools can assist in capturing and preserving STK.

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Ethics Declaration: Ethical clearance was not required for the research

AI Declaration: The following AI tools were used in the development of this paper: Turboscribe to transcript previously recorded interviews, Elicit to screen papers in the Semantic Scholar database, ChatGPT to determine the style of the references and edit and paraphrase the selected content. AI tools were used solely as support instruments and not as original content sources or scientific opinions.

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