BuildDigiCraft

New Mindset for High-quality Baukultur in Europe:

Bridging Craft and Digital

Annette Bögle, Emiliya Popova (eds.)

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2.4 Knowledge
Intellectual Output 3

Toward guidelines for the development of a higher education curriculum:

bridging craft and digital
for a high-quality Baukultur

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Abstract

The aim of the "**BuildDigiCraft**" project IO3 – Knowledge is to explore how the digital revolution of our time relates to the complex concept of knowledge and the vision of a high-quality Baukultur expressed in the European Union Davos Declaration from 2018. A more specific and limited aim is to identify how digital tools can support the knowledge production, integration of "implicit and tacit knowledge" into "explicit knowledge" and how this can ensure the transfer and creation of the cultural values expressed in the Davos Declaration.

The method was to review the output material from the different activities performed during the project addressing selected questions:

1. ***What kind of knowledge did we collect in the project?***
2. ***What methods were used for knowledge development / knowledge production?***
3. ***What is the role of knowledge in multidisciplinary research and what is the role of a multidisciplinary approach in knowledge creation? How do we transfer knowledge?***
4. ***How and where can we use collected knowledge in future? Contextualization of these questions helped to frame important links to contemporary discourse on the topic of knowledge, challenges, and approaches to knowledge production. Material presented in case studies exemplified selected outputs from pre-tasks, ISPs and lectures in relation to forms of knowledge and knowledge production.***

Results from the project show that "knowledge" is a wide concept. The project reveals that students from early research education can learn how to integrate different forms of knowledge in projects by reflecting on the interplay of actors in inter-/transdisciplinary projects and practice-based learning. The exemplified students' projects (PhDs or advanced Master's theses) show a variety of approaches to knowledge production in the field of the built environment. Common aspects discussed in their work are linked to digitalization and application.

Students' projects present emergent topics, and innovation through reconfiguring existing knowledge in connection with the rapid development of new digital tools for design and production. Digital tools are useful and common in the new production and exchange of knowledge. There is much attention paid to obtaining, testing, exploring, modeling, and visualizing the data. The ambition to address existing problems within a framework of sustainability, regeneration, efficiency, resilience, socially consensual and negotiated knowledge production and co-production is tangible, the aim being the quality of the space and sustainable lifestyle in the built environment and high-quality European Baukultur. In conclusion, the university in the up-to-date complex environment of information transfer plays an important role as a knowledge hub that shares knowledge between society, science, and industry. Individuals in higher education are given an opportunity to learn to grow in their own work as professionals. Moreover, the designer needs training, too – in learning how to make informed design decisions and how to implement the craftspeople's practical knowledge.

1.0 Topic and challenge

The aim of the **BuildDigiCraft** project IO3 – Knowledge is to explore how the digital revolution of our time relates to the complex concept of knowledge and the vision of a high-quality Baukultur expressed in the European Union Davos Declaration from 2018. A more specific and limited aim is *to identify how digital tools can support the integration of "implicit and tacit knowledge" into "explicit knowledge" in order to ensure the transfer and creation of the cultural values expressed in the Davos Declaration*.

Knowledge in its essence can be explicit or implicit, the second also including the unspoken aspects that tacit knowledge includes. Where explicit knowledge can be easily accessed and transmitted to others by articulation, codification and verbalization, the tacit and implicit knowledge is gained by personal experience and is more difficult to express and transfer. Craftsmanship is a skill level developed through implicit and tacit knowledge and passed on within the community of craftspeople.

Where in industrialized times it was important to accumulate specialized expert knowledge, which then had to be applied in a highly specialized and mostly mono-disciplinary context, in the digital era there is a strong need to learn how to integrate this specialized knowledge in an inter-/transdisciplinary setting marked by a permanently increasing level of complexity. By addressing this complexity in decision-making processes for sustainable cities and global threats in research, the culture of how knowledge is produced, developed, managed or transferred comes to light. Research practice has become highly reflexive and must be made more accountable by society. This stresses the growth of mutual learning between scientists and societal actors. More than ever, knowledge plays a key role in meeting social demands to approach and solve urgent issues in the society and knowledge democracy, where digitalization plays an important role in producing and communicating this knowledge.

Digitalization addresses the way we are handling knowledge today in terms of the increased amount and intensity of the available data and the indefinite number of complex relations that can be recognized within the specific data vs. information vs. knowledge context. However, decision-making on how data should be acquired, selected, arranged, evaluated, and communicated remains a process principally dependent on the human factor. Humans tend to rely on implicit knowledge, which also involves some sense of intuition, when dealing with specific problems that require customized decisions. Based on this, the relationship between the two types of knowledge is explored within the WP3 from different perspectives and in a multidisciplinary context; also, the general question of how knowledge relates to shaping the built environment is looked at and and how this knowledge is generated, structured and transferred within the context of digitalization.

2.0 Methodology and limitations

The investigations are mainly based on the output from the different activities performed during the project and especially the output from the Intensive Study Programs (ISPs). In order to structure this material, a set of research questions was formulated:

1. *What kind of knowledge did we collect in the project?*
2. *What methods were used for knowledge development / knowledge production?*
3. *What is the role of knowledge in multidisciplinary research and what is the role of a multidisciplinary approach in knowledge creation? How do we transfer knowledge between cultures, disciplines, technologies, methods, programs, practice, and science?*
4. *How and where can we anticipate the future demand of knowledge?*

The first question requires a historic review and a contextualization of the concept of knowledge (chapter 3.0). The examples selected after the literature review refer to an important discourse on knowledge with highlighted topics/sub-chapters: *The many faces of knowledge* by Bernt Gustavsson (chapter 3.1.), *The Nicomachean Ethics* by Aristotle (sub-chapter 3.1.2.), *The Concept of Mind* by Gilbert Ryle (chapter 3.1.3), *The Reflective Practitioner* by Donald Schön (chapter 3.1.4), Implicit, tacit and explicit knowledge (chapter 3.1.5).

The second and third question collect and compare different approaches to knowledge production (chapter 3.2), old vs. new knowledge production (sub-chapter 3.2.2), knowledge management (sub-chapter 3.2.3) and up-to-date approach to data collection, transfer and data analysis in knowledge generation (chapter 3.2.4). Formulated concepts explain the roles of disciplines in shaping the built environment.

Based on the material from the **BuildDigiCraft** (chapter 4.0), project case studies are selected to exemplify and discuss different approaches to knowledge: knowledge production (chapter 4.1), knowledge management (chapter 4.2) and students' perception of learning (chapter 4.3).

The fourth question uses the material to look into the future. This section reflects in general on discussed results from the project (chapter 4.4), highlights the future knowledge production, craftsmanship and the role of digitalization. The text specifically concerning the *Craft in a Digital Era* based on the lecture by Claes Caldenby held during the ISP1 phase discusses the necessity of re-identification of designers' work with the work of a craftsman (chapter 4.5), and a discourse is provided on Baukultur and the connection to the Davos Declaration (chapter 4.6).

Within the WP3, working guidelines for knowledge transfer to re-identify the work of the designer with the work of the craftsman are discussed in chapter 5.0 – Final reflections and guidelines.

3.0 Background theory

3.1 The many faces of knowledge

Contextualization of question 1

3.1.1 Introduction

The essay *The many faces of knowledge* by Bernt Gustavsson (2000) gives an overview of concepts of knowledge that spans from the three forms of knowledge formulated by Aristotle to contemporary discourses. He shows how Aristotle's three categories of knowledge – episteme (scientific knowledge), techne (knowledge of craft) and phronesis (ethical knowledge) – still hold relevance, not least for the application of knowledge in practice. For example, in the Swedish higher education system these three forms of knowledge have over decades been the framework for defining the criteria to be fulfilled for different academic exams.

A more commonly used conception of knowledge over the last centuries relates to the Platonic definition usually known under the term of episteme and from which the term epistemology stems. This definition of knowledge tells us that knowledge emerges from what we believe or hold to be true. What we believe is true must be supported by good arguments. The definition has its origin in the works of Plato and is based upon a distinction between *doxa*, to have a meaning or a sense of meaning, and *episteme*, to possess certain or objective knowledge. Gustavsson claims that epistemology has a dominant position in our understanding of knowledge in the Western world, specially in Anglo-Saxon philosophy.

However, the issue of practical knowledge has become a topic of increasing interest. With a background in different philosophical perspectives, the content of knowledge in different human activities has been explored, not least the relationship between the theoretical and the practical. Gustavsson brings forward Gilbert Ryle's distinction, first published in 1949, between *knowing that* and *knowing how*. The reflective practitioner, a term coined by Donald

Schön in 1983, was applied in conjunction with unspoken knowledge and knowledge in practice. At the same time, one further perspective of knowledge – practical wisdom based upon Aristoteles' tradition of ethics – has attracted the interest of researchers and thinkers. This form of knowledge has an ethical dimension, and it represents an alternative to other views.

3.1.2 The Nicomachean Ethics, Aristotle (384/322)

To understand the essence of knowledge, it is helpful to take a look at *The Nicomachean Ethics* by Aristotle. Aristotle agrees with Plato that knowledge is of what is true and that this truth must be justified in a way that shows that it must be true. Gustavsson (2000) explains how the Aristotelian conception of human knowledge focuses on a person's involvement in a number of activities or forms of life: episteme, techne, phronesis.

Episteme or theoria – represents scientific or proven knowledge and refers to understanding. *Techne or poesis* is used in connection with tacit knowledge or the reflective practitioner and represents the activity in which a person brings something into being that did not exist before (craft work, art, poetry). *Phronesis* refers to wisdom connected to and earned from practice. Phronesis is an ethically rooted kind of knowledge and can be understood as prudence, practical virtue and practical wisdom related to how practical action develops.

This conception of classifying human knowledge basically describes three different styles of thinking. And these three categories of knowledge are relevant even today. At the very beginning, for Aristotle, these types of knowledge were not structured hierarchically, they were not prioritized. Yet over time some types of knowledge were given more importance than others. For instance, *episteme* and *techne,* which root themselves greatly on facts and physical reality, are quite often given more practical value than *phronesis* is. This kind of priority setting, though in itself problematic, becomes indeed threatening when one branch of knowledge is entirely negated or diminished.

3.1.3 Knowing how and knowing that

In his book *The Concept of Mind* published in 1949, Gilbert Ryle (2002) introduces the terms *knowing how* and *knowing that*. The first refers to skills, to be able to perform certain actions, and the second to knowing how things are. Knowledge is seen as rational activity, but the two forms of knowledge are based on different kinds of rationality. Theoretical knowledge, to know that, is linked to logical conclusions. In a practical context, attention during the activity itself is the basis for the formation of knowledge. The knowledge is then tested by what we do. To *know how* thus means both what we can do and what we understand or have insight into when we act. Knowledge here means that we can perform a certain operation, a skill, and that we can explain what we have done.

3.1.4 Knowledge in practice

Architecture is a profession where knowledge is about the ability of taking well-grounded design decisions in complex situations. In *The Reflective Practitioner* (1983), the design theorist Donald Schön formulates the two fundamental concepts *"reflection-in-action"* and *"repertoire"* as essential elements of design work.

On *"reflection-in-action,"* he writes:

"A designer makes things. Sometimes he makes the final product; more often, he makes a representation – a plan, program, or image – of an artefact to be constructed by others. He works in particular situations, uses particular materials, and employs a distinctive medium and language. Typically, his making process is complex. There are more variables – kinds of possible moves, norms, and interrelationships of these – than can be represented in a finite model. Because of this complexity, the designer's moves tend, happily or unhappily, to produce consequences other than those intended. When this happens, the designer may take account of the unintended changes he has made in the situation by forming new appreciations and understandings and by making new moves. He shapes the situation, in accordance with his initial appreciation of it, the situation 'talks back,' and he responds to the situation's 'back-talk'."

The concept of "*repertoire*" is about the collection of impressions, ideas, examples and events that the designer consciously or unconsciously uses in his reflection. Donald Schön writes further:

"When a practitioner makes sense of a situation, he perceives to be unique, he sees it as something already present in his repertoire. To see this site as that one is not to subsume the first under a familiar category or rule. It is, rather, to see the unfamiliar, unique situation as both similar to and different from the familiar one, without at first being able to say similar or different with respect to what. The familiar situation functions as a precedent, or a metaphor, or … an exemplar for the unfamiliar one."

This kind of knowledge is closely related to the design process. It's individual and a result of experience, an extensive design practice based on reflection-in-action and a lifelong build of a personal repertoire.

3.1.5 Implicit, tacit and explicit knowledge

A contemporary approach defines knowledge as information that is relevant, actionable, and based at least partially on experience (Leonard & Sensiper, 1998). Three basic categories of knowledge are differentiated and depend on how the information is obtained: explicit, implicit, and tacit. Different categories interact in the information transfer process to form a model of communication, learning and development. Explicit knowledge is shared through combination and becomes tacit through internalization, while tacit knowledge is shared through socialization and becomes explicit through externalization.

Explicit or documented knowledge is the most basic form of knowledge and is easy to pass along since it is accessible by written means. When data is processed, organized, structured, and interpreted, explicit knowledge is obtained. Explicit knowledge is easy to articulate, record, communicate, and store.

Implicit or applied knowledge is the practical use of explicit knowledge, such as the necessity of performing a definite task. This could spark a conversation between the partners about the options or methods of completing the task regarding the expected outcomes, leading to a well-founded determination of the best course of action to take. A team member's implicit knowledge would educate the conversation on how to do something and what could happen. Additionally, the best practices and transferable skills obtained from a task to a different task are examples of implicit knowledge.

Tacit or understood knowledge is personal knowledge gained from personal experience and context. This is the knowledge that, if asked, would be difficult to explain, articulate or present in tangible form. Tacit knowledge is the application of implicit knowledge specific to a person's needs, so it is a significant resource for many activities, especially innovation. The tacit dimensions of individual knowledge are not publicly available unless embodied in the people being recruited. The tacit dimensions of collective knowledge are woven into the organization's structure and are not easy to imitate. Therefore, tacit knowledge is a source of competitive advantage. The creativity required for innovation stems not only from evident expertise but also from an invisible source of experience.

3.2 Approaches to knowledge production

Contextualization of question 2 and 3

3.2.1 Introduction

A reflection by Roode Liias, Tallinn

When we think about the pyramids in Egypt, for example, we know that they were built up to 5,000 years ago. So the facts and data about these structures have been there ever since then – the researchers and even the general public (e.g., tourists) have had the possibility to see these artefacts and admire the quality of engineering from ancient times. The textbooks about history and about the pyramids have provided full details on how these artefacts, consisting of millions of stony blocks, were built. Though there are several unanswered questions about how in fact the pyramids were erected, the content of these books has become our common knowledge about construction processes – including the construction process of pyramids and also about how the structure developed.

New survey technologies based on laser scanning have made it possible to study the structures of the pyramids in depth, and it emerges that quite often only the envelope structures consist of solid stone blocks. Also, smaller pieces of stones were used to fill in the main body of the pyramids. Scanning the river Nile and the desert around the pyramids has provided more and more information about the logistics of transporting and prefabricating the blocks and also about the working conditions and technology used on the construction sites. Accordingly, the deeper study of artefacts allows us to uncover new information, and the amount of new knowledge on the objects of study has rapidly increased in society. To acquire and produce new knowledge, new data and information first have to be found.
Not only new data is needed, but we also have to use the existing – though sometimes rather defective – knowledge that provides reasonable new interpretation possibilities.

Following Aristotle's classification of knowledge, we now have scientific knowledge and based on it, we try to explain everything we have around us. Today, all engineers can explain – with scientific knowledge as the premise – how a pyramid must be built to guarantee stability of the structure. But the next step is based on the question of how these artefacts were in fact created. To this end, we use our knowledge of craft (*techne*) – the logic of how things are normally developed. Experts start to furnish this gap in our knowledge – how moving and lifting these heavy blocks was possible – with the common know-how about different technologies. And finally, we use our ethical knowledge about the society of those times and try to generate the bigger picture of how the construction works were achieved – what were the working conditions and tools, what did the workers eat and where were they accommodated?

Therefore, deeper studies of the major artefacts and various smaller objects together with the critical interpretation of existing knowledge give us the chance to develop common knowledge for society. Common knowledge is accessible to everyone in society and used by all – based on our common knowledge, we educate our children and our society as a whole. In order to create this common knowledge, researchers have to actively use all the contemporary methods and tools for picking up new information and sharing it in society and to the public.

3.2.2 Knowledge production

Approach 1 for knowledge production

Old vs. new knowledge production (by Cooper, Klein and Bunders according to Gibbons)

The concept of knowledge production in building cultures is evolving. There are serious challenges involved in achieving sustainable development when collaborating communities, researchers and decision-makers increasingly seek to tackle problems that require both specialized knowledge and integrative skills to cope with complexity.

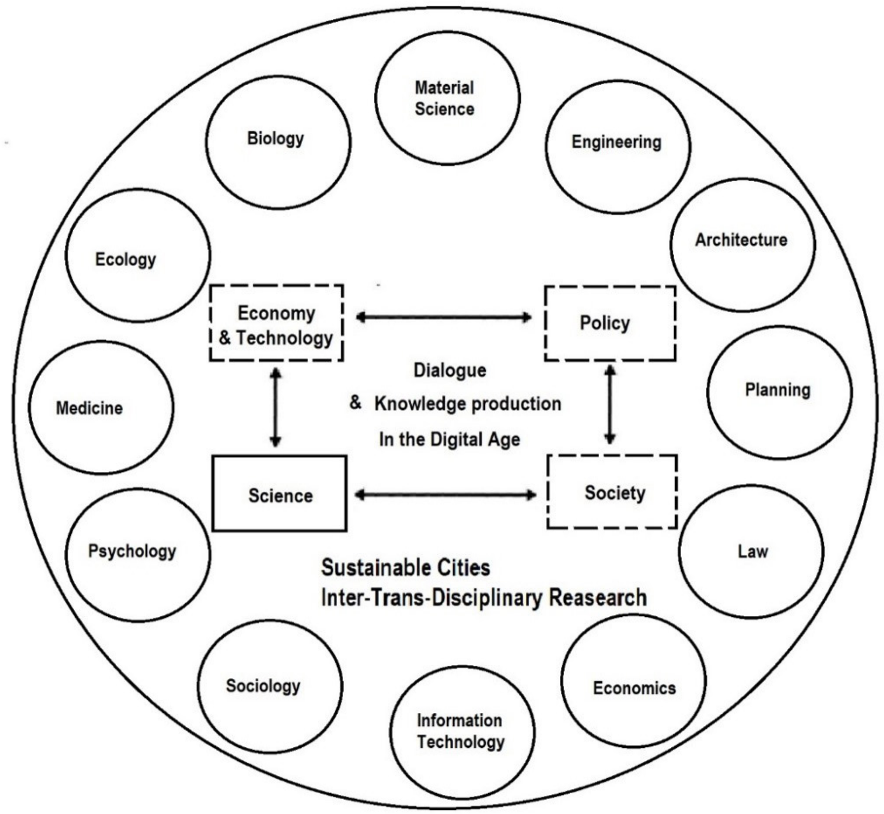
The perspectives on knowledge production have evolved especially over the last five decades when science has been facing the growing complexity of real-world problems, social relevance and demand for collaboration between researchers, new research questions going beyond one discipline (Klein, 2015). A new social distribution of knowledge is occurring as a wider range of organizations and stakeholders contribute skills and expertise to problem-solving (Fig[●1]).

In 1994 Gibbons and colleagues (Gibbons et al., 1994) proposed that a new mode of knowledge production was fostering synthetic reconfiguration and recontextualization of knowledge. The concept of "*knowledge production*" understood as academic, investigator-initiated and discipline-based (labeled "Mode 1") has been challenged by a new concept due to an urgent need for rethinking science and its relationship to society. The "old" knowledge was characterized by theory-building and testing within a discipline toward the aim of universal knowledge, while the "new" knowledge (labeled as Mode 2) is generated in the context of application, much greater diversity of the sites and types of knowledge produced. In the discourse of knowledge production, the complementarity of Mode 2 transdisciplinarity develops a distinct but evolving framework to guide problem-solving efforts beyond disciplines. Though it has emerged from a particular context of application, transdisciplinary knowledge develops its own distinctly theoretical structures, research methods and modes of practice. In 2001, however, Nowotny, Gibbons and Scott extended Mode 2 theory in arguing that contextualization of problems requires participation in the agora of public debate (Nowotny et al., 2003).

Cooper (2002) after Nowotny et al. (2001) argued that science had become central to the generation of wealth and well-being, resulting even more than in the past in the production of knowledge becoming a social activity, both highly disseminated and very reflexive. Cooper after Gibbons et al. distinguished old vs. new knowledge production in the context of new global trends influencing research, like sustainable development, virtual organizations and the rise of "e-science" as well as public (including media) involvement in knowledge production.

The discourse of knowledge production for problem-solving is not new. It was fundamental to conceptions of interdisciplinarity in the first half of the 20th century (Klein, 2015). There was a growing pressure to solve problems raised from society and a more important position of transdisciplinarity (TD) with solving complex problems, "trans-sector participation" of stakeholders in society and "team-based science." Demands for TD arrived along with a wider crisis in the benefiting of dominant forms of knowledge, responsiveness to human rights accountability, and democratic participation.

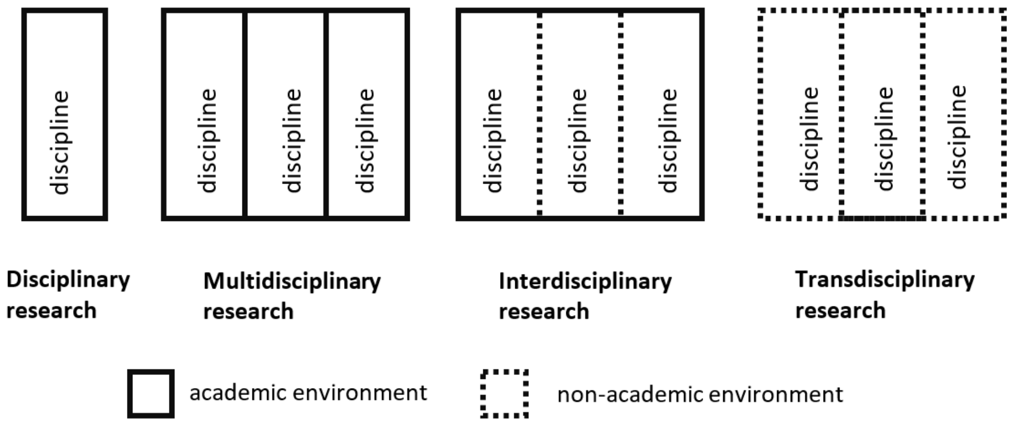
As a consequence, a shift is observed today from solely "reliable scientific knowledge" to inclusion of "socially robust knowledge" that transgresses the expert/lay dichotomy.



Fig[● 1] View of different processes involved in knowledge production (based on Klein et al., 2001, and Cooper, 2002, and modified by A. Kaczorowska).

The new trends in knowledge production include fostering new collaborations not only between disciplines in the academic context, but also partnerships between the academy and society, including non-academic partners. A distinction between disciplinary, multidisciplinary, interdisciplinary and transdisciplinary research is shown in Fig[● 2] (HafenCity University, 2018).

Multidisciplinary and interdisciplinary research can be seen as continuum between monodisciplinary research and transdisciplinary research. Transdisciplinary research developed mainly during the 1980s and early 1990s (Bunders et al., 2010). Klein (2001) defines transdisciplinarity as: *"a new form of learning and*



Fig[●2] Visualization of different types of research in relation to disciplines involved in the academic and non-academic context (HafenCity University, 2018).

problem-solving involving co-operation between different parts of society and science to meet complex challenges of society. Transdisciplinary research starts from tangible, real-world problems. Solutions are devised in collaboration with multiple stakeholders." Transdisciplinary research is rooted in local scientific, cultural, and political practices that differ for each country.

The notion of hybridization of knowledge production and modes of inquiry in architecture and urban planning became a widespread and intensively debated issue within the scientific and academic communities at the beginning of the millennium (Doucet & Janssens, 2011). Transdisciplinarity explores new fields of investigation and research. So-called "hybrids" of knowledge production are often formed in gaps between sub-disciplines. Doucet and Janssen argue that new hybrid modes of inquiry, practice and learning have the capacity to overcome past splits of theory, history, and practice. Transdisciplinarity in architectural or urban design involves ethics, aesthetics and creativity inside of disciplinary and professional work, incorporated with social and political, normative, and ethical questions. New objects are brought into view in knowledge production, like practices in new configurations that contextualize and reassess both theory and learning, including the understanding of the general public. Klein (2014) argues that a transdisciplinary vision of architecture, urbanism and design according to Doucet & Janssens (2011) joins the epistemological perspective of systems theory with an "in-practice model" of design and learning. "Hybridization" also recognizes the greater relationality of knowledge today. Tasks lie at the boundaries and in the spaces between systems and sub-systems, requiring collaboration among a mix of actors.

Bunders et al. (2010) provides a foundation for "*knowledge democracy,*" when ideal conditions allow dominant and non-dominant actors to have equal access and the ability to bring this knowledge forward to contribute to solutions for societal problems. He distinguishes different approaches to knowledge production:

1. **The self-referential knowledge production style** (mono-, multi- and interdisciplinary academic research) – might consider questionnaires or polls from the stakeholder groups related to the issue. These research projects certainly develop the academic expert's view on the issue.
2. **The knowledge dissemination style** – can be described as a process in which knowledge is transferred to the wider public and disseminated in relation to different activities, for example by promoting improvements in lifestyle.
3. **The mutual learning for knowledge production between scientists and societal actors' style** – allows a joint analysis by societal decision-makers and the public with academic researchers to tackle complex multi-stakeholder problems.
4. **The knowledge co-creation between scientists and societal actors, with specific focus on non-dominant actors' style** – is captured in the Interactive Learning and Action (ILA) approach that covers cyclic multi-phase programs often over a longer period with dominant and non-dominant actors supported by the transdisciplinary researchers.

The new knowledge production requires diverse types of action. Building on Cooper (2002), Bunders et al. (2010), and Klein (2015) after Gibbons et al. (1994), it is possible to characterize new knowledge production in comparison to the old way (Table[●1]). New features include, for example, collaboration of at least two or more disciplines, dissemination and partnerships through networks, e-science and interaction electronically mediated, application-based problem-solving, consensual and negotiated knowledge production, innovation predominantly through reconfiguring existing knowledge. While Cooper (2002) addresses interdisciplinary knowledge production, Bunders et al. (2010) and Klein (2015) refer to transdisciplinary work, building on Gibbons et al. and Mode 2 (1994).

The context of knowledge production includes for example the commercialization of research, the development of mass higher education, the growing role of the humanities in the production of knowledge, globalization (world brands and massive data flows), etc. (Nowotny et al., 2003). "Knowledge" is sometimes viewed not as a public good, but rather as "intellectual property." Knowledge is often produced, accumulated and traded like other goods and services in the knowledge society. In the process, a new language has been invented – a language of knowledge application, relevance, contextualization, reach-out, transfer and management.

3.2.3 Knowledge management

Approach 2 for knowledge production

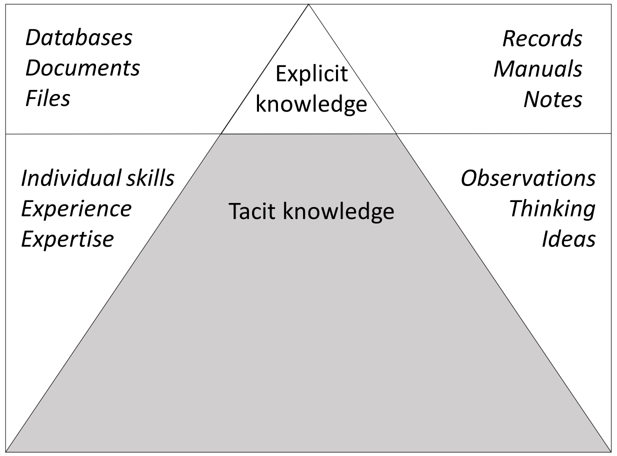
Knowledge management (also used as a term for knowledge exchange) is the process of creating, sharing, using and managing knowledge (Smith & Hairstans, 2017, after Girard & Girard, 2015). This process requires different approaches when including different types of knowledge. There is a lot of explicit knowledge to be found in codes, publications, in people and organizations. Still, the majority of knowledge regarding the built environment, including construction, is implicit and tacit.

Explicit knowledge in form of data, records, and documents, for example (in academia: journal publications, databases, books, websites and videos) is relatively easy to disseminate. On the contrary, tacit knowledge is difficult to transfer by means of writing or speaking. It is embedded in people, organizations, societies, and cultures. It comes from experience, thinking, competence, and commitment. In academia, tacit knowledge is found in workshops, conference discussions, internships, and exchanges. Fig[●3]

Table [●1] Old vs. new knowledge adopted from Cooper (2002), after Bunders et al. (2010) and Klein (2015) after Gibbons et al. (1994).

Old knowledge production	New knowledge production in the digital era
Disciplines and dissemination	
Single discipline-based	Inter-/transdisciplinary, involving a diverse range of specialists, academics and non-academics, self-referential knowledge production style, incorporates ethics, aesthetics and creativity inside of disciplinary and professional work, transdisciplinary closely involves design professions
Problem formulation governed by interests of specific community	Problem formulation governed not only by interests of actors involved in application but also broader interests of society, incorporated with social and political, normative and ethical questions
Dissemination discipline-based through institutional channels	Dissemination through collaborating partners and social networks; public debate encouraging improvements in lifestyle and behavior
Organizations and interaction	
Mediated through face-to-face or paper-based communications	The rise of "e-science," interaction electronically mediated over the Internet and digital platforms
Quasi-permanent, institutionally-based teams	Short-lived, problem-defined, changing participants, non-institutional or mixed teams
Hierarchical and conservative team organization	(Non-) hierarchical and temporary team organization
Static research practitioners operating within discipline/institution	Mobile research practitioners operating through networks, institutional and non-institutional channels
Problem-solving, science model, knowledge production and application	
Problems set and solved in (largely) academic context	Problems set and solved in application-based context
Newtonian model of science specific to field of inquiry	Emergent theoretical/conceptual framework not reducible to single discipline, knowledge co-creation between scientists and societal actors, hybridization
Separate knowledge production and application	Integrated knowledge production and application via testing, building models, places practices in new configurations, contextualizes and repositions both theory and learning
Research practice and approach to innovation	
Research practice conforms to norms of discipline's definition of scientific accountability	Research practice reflexive and socially accountable, mutual learning for knowledge production between scientists and societal actors
Static research practice defined by "good science"	Dynamic research practice characterized by on the move problem-solving, joint problem formulation between scientific and societal actors
Normative, rule-based, "scientific" knowledge produced	Consensual, continuously negotiated knowledge, produced "experience"
"Innovation" seen as production of "new" knowledge	"Innovation" also seen as reconfiguration of existing knowledge for new contexts, scientifically certified and action-oriented knowledge, hybridization of knowledge production, entrepreneurship

shows that explicit knowledge, knowing the that, what and why, constitutes an estimated 10 percent of our knowledge repository as humans, while tacit knowledge, knowing who and how, makes up 90 percent of our total knowledge base (Smith & Hairstans, 2017, after Wah, 1999; Bonner, 2000; Lee, 2000).



Fig[● 3] Shares of types of knowledge: explicit and tacit /implicit (drawn after Smith & Hairstans, 2017).

Explicit and tacit are not separate modes of knowledge but function as a continuum (Smith & Hairstans, 2017). It is necessary to explore the concept of knowledge conversion, sometimes referred to as knowledge transfer, where knowledge is exchanged from one type to another. Explicit knowledge can be transferred to other explicit knowledge – this is called a "combination." Knowledge is a human function and when people internalize the knowledge, making it part of their activity, they contribute to "internalization" when explicit knowledge is transferred to tacit conversion. Communicating knowledge in spoken or written form is to converse tacit knowledge to explicit knowledge and is called "externalization." Lastly, tacit to tacit forms of transfer are referred to as "socialization" and tend to be informal – experienced in the very act of doing (Table[● 2]).

The contemporary role of academia has changed as it serves as a facilitator of emerging modes of learning, knowledge production and knowledge exchange as described by Smith & Hairstans (2017) after Youtie and Shapira (2008). The new role of universities to advance technological

Table [● 2] Knowledge conversion scenarios and terms (drawn after Smith & Hairstans, 2017).

KNOWLEDGE CONVERSION	TERM
EXPLICIT TO EXPLICIT	COMBINATION
EXPLICIT TO TACIT	INTERNALIZATION
TACIT TO EXPLICIT	EXTERNALIZATION
TAICIT TO TACIT	SOCIALIZATION

innovation and economic development as "knowledge hub" defines a change for many universities from the late 20th century until now. It seeks to animate indigenous development and innovation, spanning between industry, the government and society. High-performing institutions are those which effectively advance, distribute and recombine tacit knowledge. Some universities in parallel also serve like a 19th century "storehouse of knowledge," or a "knowledge factory" for research, training and commercialization (late 19th century to the end of the 20th century).

APPROACH	TIME & CONTEXT	ROLE OF THE UNIVERSITY IN SOCIETY
TRADITIONAL	Prior to XIX C. / CRAFT PRODUCTION	Storehouse of existing historic knowledge by elitist group above society.
SUPLIER	XIX C.- late XX C. / INDUSTRIAL MASS PRODUCTION	University seen as a factory of knowledge that supplies research, education, fulfils commercial purposes, and contributes to development of new technologies.
HUB	Late XX C. – present /POST-INDUSTRIAL ECONOMY	Integrated institution in the region creating synergies with industry, government and society.

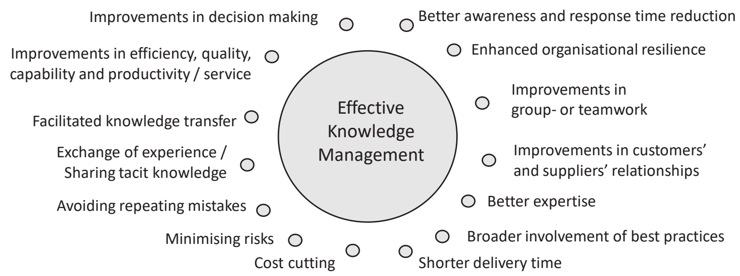
Table [● 3] Transformation of the university's role in society (drawn after Smith & Hairstans, 2017).

Community and non-governmental organizations (NGOs) play a special role in knowledge exchange fostering innovation in a particular sector or interest area. The contemporary role of academia has changed as it serves as a facilitator of emerging modes of learning, knowledge production and knowledge exchange.

Effective knowledge management can be seen as a key driver to increase organizational competitiveness. The future will value effective knowledge management (transfer of knowledge) if it becomes a key survival aspect for an organization to keep its competitiveness. It has been shown by various studies that poor project (activity) performance is linked with a lack of knowledge and/or ineffective learning. When single project failures are combined, low productivity, capability gaps, poor performance, higher learning costs are the result. By applying knowledge management at the appropriate moment (not in the distant future), that kind of loss can be avoided. Several benefits can be named that are dependent on effective knowledge management as provided by Yap et al. (2022, see Fig[● 4]).

B1	Efficiency improvement
B2	Quality improvement
B3	Time reduction (response time reduction)
B4	Delivery time reduction
B5	Decision-making improvement
B6	Employees' experience exchange/facilitate transfer of knowledge
B7	Product/service improvement
B8	Customers' and suppliers' relationship improvement
B9	Costs cuts/reduced costs
B10	Group/teamwork improvement
B11	Reducing rework
B12	Improve capability and productivity
B13	Better expert judgement
B14	Continuous improvement
B15	Reducing the cost of poor quality
B16	Avoid repeating past mistakes
B17	Retain tacit knowledge
B18	Minimise risk
B19	Better response to organisation changes
B20	Better sharing of best practices

Fig[● 4] Sample benefits from effective knowledge management as provided by Yap et al., 2022.



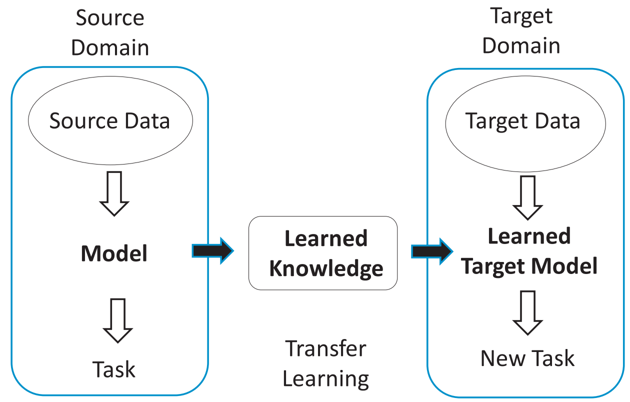
Fig[● 5] Sample benefits from effective knowledge management (drawn after Yap et al., 2022).

3.2.4 Up-to-date approach to data collection, transfer and data analysis in knowledge generation

Approach 3 for knowledge production)

To be able to use the collected knowledge, we need to find the right methods and tools to be able to transfer it. Knowledge transfer is not a copy and paste approach, you need to take account of new perspectives, mapping technologies, assumptions. It is especially important when new knowledge is based on big data analytics: how to reuse the knowledge acquired and how current knowledge can be extended. Fig[● 6] by Xu et al (2022) shows the basic transfer process of knowledge (learning). In the construction sector, there are project-based workflows; knowledge transfer rarely happens in between projects.

Collecting large amounts of qualitative data and working with different data sets involves several aspects of research,



Fig[● 6] Transferring learning from source domain into target domain (drawn after Xu et al, 2022).

such as comparison and generalization. The merging of data from several qualitative studies offers opportunities to address new research issues by comparing research differences. This comparison can be achieved using metadata, for example, about the focus of research. Some sets allow comparing differences in disciplines. Researchers can ask questions that individual projects would not be able to answer.

Knowledge production in the digital era can be a tacit experience. Knowledge and skills are considered to be key human capital elements of transforming and building a sustainable environment (Modesitt, 2016). Due to the growing complexity and digitalization in disciplines involved in shaping the built environment there is a need to rethink knowledge production in relation to craftsmanship and contemporary challenges. Digital technology (software of immaterial design with immaterial making) is eliminating the separation between design and making that had existed since Leon Battista Alberti and the renaissance. Knowledge production in architecture is often linked to seamlessly produced “experience” rather than just artefacts. Here, architects have been turning to software developed for other fields. Modesitt argues that digital workflows can re-engage craftsmanship and connect design intelligence with material intelligence.

4.0 Knowledge in the BuildDigiCraft project

Knowledge in the **BuildDigiCraft** project has been identified as one of three major elements of high-quality Baukultur together with Process and Material. Planning, design and maintenance of our built environment is driven by knowledge gained through experience, facts and perception and is available as explicit and implicit knowledge. It also includes tacit knowledge, which encompasses work by hand as well as mind. Therefore, Knowledge was integrated as a major subject in the **BuildDigiCraft** structure. The concept of Knowledge in relation to Baukultur was explored during the project from different perspectives – through input from various lecturers to individual and joint exercises where the participating PhD students elaborated and reflected upon what knowledge, knowledge production and knowledge transfer is and could be. Special attention was paid to craftsmanship in a digital environment; how digital tools can support the integration of implicit knowledge into explicit knowledge, including the aim of transfer and creation of cultural values. Three perspectives of knowledge, gained from the **BuildDigiCraft** project, will in the following be presented. They are chosen with the aim to shape a picture of the **BuildDigiCraft** process as well as to provide a basis for final reflections and guidelines.

The first view shows examples of students' work that relate to questions of what and why knowledge is produced and how this work contributes to knowledge production. As the participating students came from different research discourses, mainly from research groups in architecture and in engineering in the Nordic/Baltic context, the discussions during the smaller workshops and the common seminars covered quite a broad spectrum. This broad output was organized in terms of what, how, and why knowledge is produced and is relevant for a sustainable Baukultur. The second view exemplifies how students approach knowledge management and conversion of knowledge (explicit, tacit, implicit). The third perspective specifically points at the difficulties in distinguishing knowledge from information, especially in a digital context where the data and digital information is perceived by many as knowledge. Here, a demand for future knowledge is presented by students and exemplified. A fourth view is related to the concept of knowledge and learning by students. Finally, a fifth view, formulated by the invited lecturer Claes Caldenby, professor emeritus in Theory and History of Architecture at Chalmers, looks ahead and discusses the concept knowledge in relation to the design situations in which the wise decisions that shape our built environment are taken.

4.1 Views of knowledge production

Analysis by Anna Kaczorowska, Chalmers

This analysis is based on material collected during the Intensive Study Programs (ISPs) that includes individual students' pre-tasks, lectures, group works and seminars, and work with a compiled glossary. A framework of criteria of new knowledge production after Cooper (2002), Bunders (2010) and Klein (2015) has been used to organize the material. The aim was to answer the questions what, why and how with regards to students' approaches to knowledge production, represented in the project material and addressing following trends:

1. Applied knowledge production with a focus on innovation (application-based problem-solving, emergent conceptual frameworks, innovation through reconfiguring existing knowledge) – **WHAT knowledge is produced**?
2. Multi-/inter-/transdisciplinary knowledge production in transient and problem-defined teams, virtual organizations and platforms (dissemination through partners and networks, development of "e-science" and e-knowledge production, interaction electronically mediated over the Internet) – **HOW knowledge is produced?**
3. Socially consensual and negotiated knowledge production, co-production (public realm, knowledge production highly disseminated and very reflexive) – **WHY knowledge production is important or relevant?**

Special attention has been paid to material from three explicit tasks given to the students (PhD students and a minor group of M.Sc. students):

- **ISP2**: Reflections on *Knowledge transfer* after the keynote lecture: *"Big or small data for big and small problems?"* by Helle Rootzen. (16 students)
- **ISP2**: Reflections on *Knowledge & Data Analysis*. (16 students, four groups)
- **ISP3**: Reflections on the relation *Process, Knowledge, and Material* in relation to own PhD/M.Sc. projects. (15 students)

The content of the tasks was provided to students as follows:

"Knowledge Transfer and Data Analysis"

Pre-task 4: Assignment (ISP2)

Keynote lecture: *"Big or small data for big and small problems?"*
by Helle Rootzen, Feb. 18, 9:00–10:00 a.m.

1. Think on a situation where you are aware of how data analysis made a project better. Why was it better? Please look at different sources like papers, books, the Internet to find a good example.
2. In the context of your own projects: what is the data you use? How do you identify and acquire this data? How do you use it? How do you (plan to) interpret/evaluate it?
3. During the keynote lecture by Helle Rootzen have in mind the following question: how can you see that the principles and ideas that Helle talks about could be used in your own project, and what would be the benefits?

ISP 2, Day 4 Knowledge, Group work and presentation of the Preparatory task 1 *"Knowledge Transfer and Data Analysis"*

Mapping Guidelines:

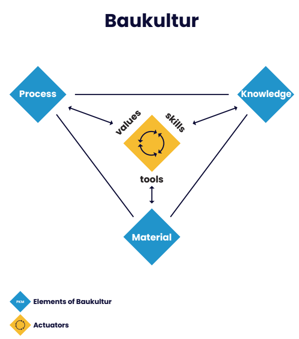
1. Present to each other your Preparatory task *"Knowledge Transfer and Data Analysis."*
2. Group work: collect and categorize together as a group the advantages and disadvantages identified by your examples on how data analysis made a project better.
3. Contribution to the Glossary: focus on the concepts of *Knowledge, Data and Data Analysis.*
4. The group speakers present the outcomes of the Group work task to the audience.

"Process—Knowledge—Material—Reflection"

Pre-task 1: Assignment (ISP3)

Reflect on your individual project (PhD project/Master's thesis/project of personal interest) in respect to the **BuildDigiCraft** graph model (Fig[● 7]).

Analyze and reflect on your individual project by answering the following questions:



Fig[● 7] **BuildDigiCraft** graph model.

1. What is the Process, what is the Material and what is the Knowledge that you are addressing and using in your (PhD) project, and what is the Process, Knowledge, and Material that you would like to derive from it?
2. How do you see the relation between the Process, Knowledge, and Material in the context of your work?
3. What are the values you are following/addressing in your project?
4. Which skills are you applying and which are the new skills that you are developing within your project?
5. What tools do you use and plan to use?
6. Try to define the term Baukultur in your own words and in respect to your individual project.

Table[● 4] exemplifies how the students responded to the questions: WHAT was the knowledge production, HOW was knowledge produced and WHY was knowledge production important and relevant?

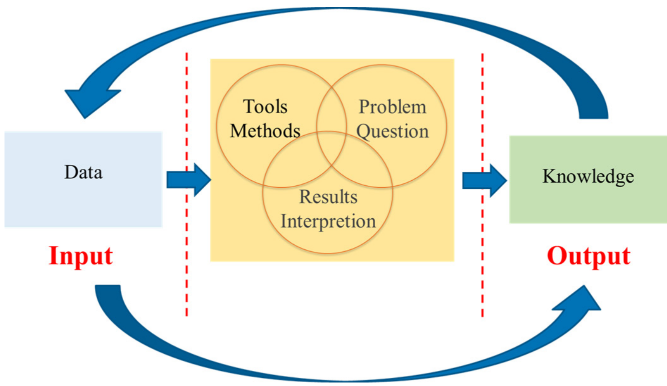
WHAT – knowledge is produced?

The exemplified students' projects (PhD or advanced Master's thesis) showed a variety of approaches to knowledge production. For most of the students, the aim for knowledge production had a strong link to a possible application. In answer to the question "WHAT knowledge production?", the students' projects addressed emergent, not sufficiently discussed or recently debated topics, often calling for innovation through reconfiguring existing knowledge. Their projects adopted the relation between the physical and the digital world easily and there doesn't seem to be anything questionable in knowledge production. Debatable was what kind of knowledge was able to be

Table [● 4] Evaluation of the material from Preparatory tasks in relation to knowledge production and questions: what, how, and why?

ISP/Tasks	**WHAT – knowledge is produced?**	**HOW – knowledge is produced?**	**WHY – knowledge production is important and relevant?**
	(E.g.: applied knowledge production with a focus on innovation/application-based problem-solving, emergent conceptual frameworks, innovation through reconfiguring existing knowledge)	**(E.g.: multi-/inter-/transdisciplinary knowledge production in transient and problem-defined teams, virtual organizations and platforms/ dissemination through partners and networks, development of "e-science" and e-knowledge production, interaction electronically mediated over the Internet)**	**(E.g.: socially consensual and negotiated knowledge production, co-production/public realm, knowledge production highly disseminated and very reflexive)**
ISP 2 / Pre-task 4 *"Knowledge Transfer"*	Knowledge from data analysis: digital analysis of data in *"Survey, construction, conservation, and restoration," "The possibility of recording current state of construction of building with efficient, fast, non-invasive techniques,"* this knowledge *"enables more complete studies and accurate interventions"* – **PhD student 1**, Gdańsk *"2D image analysis"* – **PhD student 2**, Riga *"The essential geometrical, structural, and architectural potentials, limits, and qualities"* of *"the behavior of phenomenon of concaved paper and blade of measuring meter"* – **M.Sc. student**, Helsinki Reconfiguring existing knowledge from data analysis *"GIS with remote sensing"* to get the data from the existing situations – **PhD student 1**, Helsinki Modeling impact of scenarios in urban planning – **PhD student 2**, Gdańsk *"Applying machine-learning to optimize architectural design"* – **PhD student**, Tallinn Digital modeling "To understand the real-world problems" – **PhD student 3**, Gdańsk & **PhD student 1 DTU**, Copenhagen	*"Devising new hybrid disciplines and operations between design and science that advance the prospect of establishing future biophilic environments"* – **PhD student 1**, Gdańsk Elaborated *"physical and digital studies"* – **M.Sc. student**, Helsinki *"Generating new physical or digital prototypes"* – **PhD student 1**, Helsinki e-data from sensors collected and analyzed – **PhD student 1**, Helsinki *"Provide quantitative analysis"* – **PhD student 1**, Gdańsk Modeling and simulations – **PhD student**, Tallinn *"BIM modeling"* – **PhD student 1**, Gdańsk *"Assessment of sustainability performance"* of buildings – **PhD student 1 DTU**, Copenhagen *"Data analysis from design to build"* – **PhD student 2**, Helsinki	*"To optimize the performance of form, material and cost"* – **PhD student 1**, Gdańsk *"The bind between making digital architecture and making resilient architecture must be secured for holistic and sustainable outcomes"* – **PhD student 1**, Gdańsk *"To simplify"* – **PhD student 2**, Riga *"To collect (data) and evaluate (…) in possible outputs"* – **PhD student 1**, Helsinki & **PhD student 1 DTU**, Copenhagen *"To evaluate behavior"* – **PhD student 1**, Helsinki *"Demonstrations of the impact of scenarios and Informing decision-makers"* – **PhD student 2**, Gdańsk *"Designing measurable, clear and concise questions/qualify or disqualify potential solutions to specific problem or opportunity"* – **PhD student**, Tallinn To diagnose *"Find the most problematic areas"* – **PhD student 3**, Gdańsk *"To understand state of the art"* – **PhD student 2**, Tallinn
ISP 2 / Day 4 Knowledge, Group work and presentation of the Preparatory task 4 (ISP2) *"Knowledge and Data Analysis"*	**Group 1**, Specific research questions: *"How to improve the buildings? How to analyze the proposed change without the actual building?"* **Group 3**: *"Design specific solution with only required data about form, cost and material"* **Group 4**: *"Gathering knowledge about addressing wicked issues," "Data vs. Knowledge"* **Group 5**: what knowledge from e-data? *"The acquired data needs to be interpreted by the skilled researcher who with his/her knowledge will discover, read, research the object"*	**Group 1**: "Model of variables and its impact on future energy consumption and spending based on previous data collected **Group 3**: experiments: *"Optimization, testing hypothesis vs. theory", "Forming a hypothesis before testing, then analyzing data and forming a conclusion"* **Group 4**: *"Statistical models and solutions, applying machines (artificial intelligence, machine learning, deep learning)"*	**Group 1**: *"Minimizing energy consumption in a building"* **Group 3**: *"New specializations and new collaborations"* **Group 4**: *"Knowledge = Wisdom"* **Group 4**: *"Data vs. Knowledge"*
ISP3 / Pre-task 1: *"Process – Knowledge – Material – Reflection"* in relation to individual project (PhD project / Master's thesis)	*"How to deal with rising water level"* – **PhD student**, Gdańsk *"Local knowledge on adaptation of digital paradigm and local craft"* – **M.Sc. student**, Hamburg *"Finding principles for design and fabrication of timber active bending structures using material behavior"* – **PhD student 1**, Innsbruck *"Wood science and structural engineering"* – **PhD student 1**, Helsinki *"Adaptability"* – **PhD student 2**, Innsbruck *"Achievability of adopting a circular economy in the built environment"* – **PhD student 2**, Helsinki	*"New tools are very helpful for researching how cultural landscape is being re-modelled"* – **PhD student**, Gdańsk *"Community-oriented"* exploration of *"off-grid housing scalable solutions"* – **M.Sc**, student, Hamburg Exploration and testing different joints, patterns, on form and placement, dimensions, literature study, *"Computational tools and programming (simulation tools, structural analysis applications) and physical tests"* – **PhD student 1**, Innsbruck *"Material selection, experimental investigation, Design" "Structural analysis, architectural design (integrated design concept), sustainable design, parametric design."* – **PhD student 1**, Helsinki *"Negotiations between disciplines"* – **PhD student 2**, Innsbruck *"To evolve and develop the existing models and framework; to come up with new frameworks or models," "Case-studying, field-studying and investigating the current, construction and architecture practices and projects"* – **PhD student 2**, Helsinki	*"Resilience = modern water society"* – **PhD student**, Gdańsk *"Bridging vernacular architecture with more technological systems," "Baukultur = standardization of best practices in construction by balancing social, ecological and economical aspects boosting a culture of continuous improvement"* – **M.Sc. student**, Hamburg *"Reducing the cost and energy for making forms using designed elements, assembled and dissembled, and shaping different forms"* – **PhD student 1**, Innsbruck *"Value: sustainability, structural efficiency, integrated architectural and structural design concept, wood-only connection"* – **PhD student 1**, Helsinki *"Adaptability refers to the need to reach balance between the selection of a specific behavior and the consideration of a large variety of behaviors"* – **PhD student 2**, Innsbruck

obtained from digital data ("What knowledge from e-data?", Group 5, Workshop on Day 4, ISP2, Fig[● 8]). Fig[● 8] showed the students' awareness of the distinction between data and knowledge and how data through a scientific craftsmanship can be transformed into knowledge.

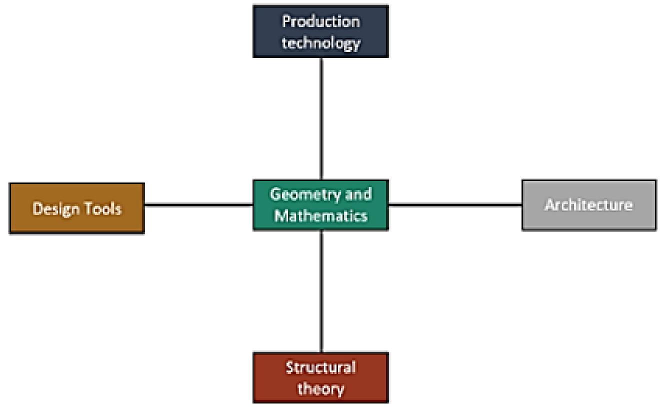


Fig[● 8] "Data vs. Knowledge" (source: Group 4, ISP2 Workshop, Task 1).

The debatable aspects of e-data related to the importance of qualities building digital work and decisions creating possibly the most reliable implications for the physical objects and places. The problem formulation is governed by broader interests of society. Projects addressed multidisciplinary, inter-/transdisciplinary aspects.

One PhD work discussed the mathematical breakthrough in geometry and how it had led to new opportunities to understand the physical world surrounding us. With inspiration from history, where geometry was a main precondition for many of our historic built masterpieces, he wished to resurrect geometry in architecture and engineering, and specifically for the use of accessible simple building blocks. Different mathematical representations have advantages and disadvantages in different situations since their underlying mathematical foundation allow for different types of manipulation, flexibility, and relaxation of physical constraints in the structural assembly, for example.

The concept of Knowledge in the PhD project was organized by seeing geometry as the basis connecting the different areas of knowledge and expertise (Fig[● 9]).



Fig[● 9] Areas of knowledge development and expertise selected for PhD project (author E. Adiels).

HOW – knowledge is produced?

Knowledge production was observed as being highly integrated and applied. The HOW was achieved by testing, building models, placing practices in new configurations, contextualizing, and repositioning both theory and learning. Digital tools were used in every project and included a variety of approaches for analysis, modeling, simulation, etc. The level of digitalization considered to be applied in projects seems to be very high and inspiring. Much work is still based on testing and experiments, where visualization plays an important role (Fig[● 10]). Additionally, knowledge production is based on *"negotiations between disciplines"* (PhD student 2, Innsbruck, ISP3, Pre-task 1).

Fig[● 10] Optimization, testing hypothesis vs. theory (source: PhD student, Helsinki, ISP4, Preparatory task 1).

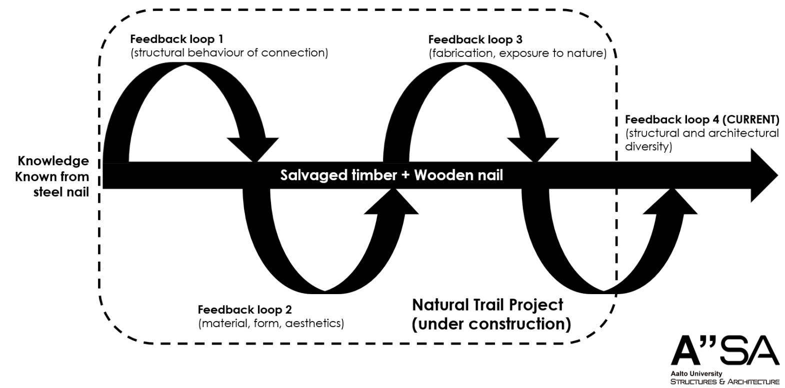
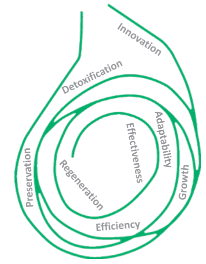


Table [● 5] Knowledge and digital futures: correlation between data, questions and models (source: students' work at the Workshop ISP2, Day 4: Knowledge, Group 1).

Data	Data	Questions	Models
Ilirjana	Spatial data User-generated data	1. How do we examine the changes of the urban morphology? 2. How are digital tools/data shaping policies and development strategies for the built environment?	Urban scenarios Digital modeling to address challenges and predict social, economic, environmental and sustainability performance of the built environment
Theo	More of qualitative data than quantitative (mixed methods). From interviews, focus groups and questionnaire questions (mostly open-ended)	Main: how can BIM be leveraged for construction management education?	Model 1: search engine query to identify relevant literature. Model 2 (theory): existing BIM-enabled strategies
Sepideh	Data derived from structural analysis Force flows in the structure	How could structural analysis help in improving the structural function and optimizing the material usage in designing a building? What are the limitations in using this approach?	Structural digital modeling/simulation Finite Element Modeling as the method
Paulina	1. Thermal imagining 2. Meters readings 3. Previous refurbishment works 4. User opinions	1. How to improve the buildings? 2. How to analyze the proposed change without actual building 3. How to reduce the risk of misinterpretation	Model of variables and their impact on future energy consumption and spending based on previous data collected
Egils	2D data to generate 3D spatial model	How can a 3D model of a city/city block can be helpful in planning? How to justify the cost of a digital twin city model? What sort of data is needed to add higher value to the 3D model?	Spatial model with the opportunity to add multiple layers and run different analyses and scenarios

There was broad understanding among students that future building cultures will work on building models in the virtual world to gather greater knowledge about the real world from simulations of data variables in these models. The most highlighted aspect of the workshop session: "Knowledge and Digital Futures" in the ISP2 workshop on Day 4 was related to data and models. Group 1 presented a table framing the connections in students' research work between data, questions and models. Students examined how it is feasible to answer key research questions with designed models based on available data (Table[● 5]).



Fig[● 11] Principles of knowledge production (source: PhD student 2, Helsinki, ISP3, Pre-task 1).

WHY – is knowledge production important and relevant?

A visible ambition in students' projects was to solve/address existing problems within a framework of sustainability, regeneration, efficiency, resilience, socially consensual and negotiated knowledge production/co-production. Moreover, by answering a question WHY? (Fig[● 11]), knowledge production was often highly disseminated and very reflexive ("*Knowledge–Wisdom*" source: Group 4, ISP2 Workshop) when facing social, normative, and ethical questions.

4.2 Views of knowledge management

Reflecting on question 3 in relation to BuildDigiCraft

The focus of the pre-tasks and group work in the ISPs was set on identity – creating a distinguishing character of a building or structure through architecture; being alive – through the use of a *Baukultur* approach in the design; social issues – in some way informal, organized by members of a club or a group of people; aesthetics – concerned with beauty and appreciation of beauty; emotional issues – openly displayed and invoking a feeling and being future-oriented – an investment in the living spaces for a vibrant future.

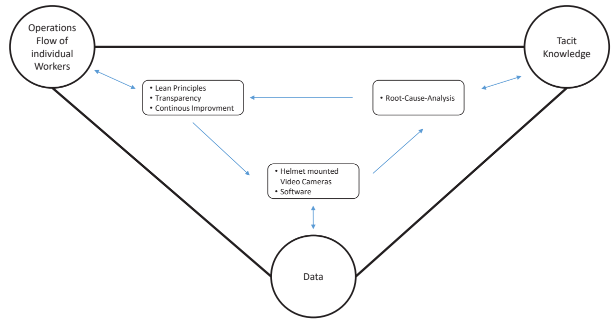
"Built environment should honor life which is in balance with nature and human knowledge."

Students were familiar with the terms "tacit, explicit, implicit knowledge" and referred to them often in their work. In Pre-task 1 (ISP3): ***"Process–Knowledge–Material–Reflection,"*** Master's students at the HafenCity University described the topic of community-based digital design and fabrication, arguing for high-quality Baukultur (Fig[● 12]) that respected local knowledge and adapted local craft.

Fig[● 12] Presented aspects of knowledge and Baukultur in Master's students' work at HafenCity University.

In discussing the topic of Baukultur, Master's students presented *"tacit knowledge"* as an important component of their own project work (Fig[● 13]). Here, tacit knowledge is linked to best practices in construction in relation to work of individual workers, operations, and data in community-based digital design and fabrication.

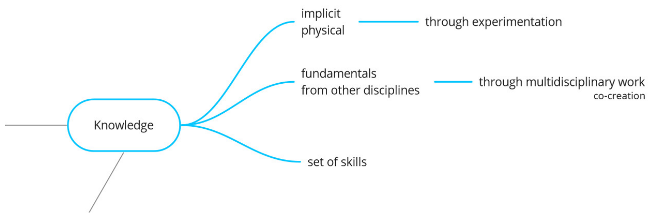
Fig[● 13] The subject of tacit knowledge for high-quality Baukultur in the Master's students' work at HafenCity University.



Baukultur = Standardization of best practices in construction by balancing social, ecological and economical aspects boosting a culture of continous improvement.

Fig[● 14] Process–Knowledge–Material–Reflection (source: PhD student 3, Helsinki, ISP3, Pre-task 1).

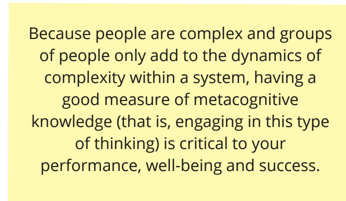
Another student indicated the importance of *"implicit knowledge"* applied via experimentation, calling it physically embodied in craftsmanship and materiality (Fig[● 14]).



For another student, a PhD student from Riga Technical University, *"learning by doing"* in research and design work was a way of knowledge production. This showed the importance of "knowledge conversion," sometimes referred to as knowledge transfer as a key aspect of learning, where knowledge is exchanged from one type to another (chapter 3.2.3. *Knowledge management*, source: Smith & Hairstans, 2017). Here, research and design work enabled all types of knowledge. Implicit knowledge became the practical application of explicit knowledge. A transfer of explicit knowledge to another explicit is called "combination," and "internalization" of the knowledge when students transferred explicit to tacit individual knowledge, garnered from personal experience and context. When students communicated this tacit knowledge to spoken or written form explicitly, it was called "externalization." "Socialization" tended to be informal, experienced in the very act of doing, where one tacit form of knowledge was converted to another tacit form.

4.3 Students' perception of learning

Students from Group 2 at the ISP2 workshop highlighted aspects of knowledge in the learning process as introduced by Krathwohl (2002). The new dimension of knowledge according to the revised taxonomy by Krathwohl brought a perspective of knowledge into the field of education and learning as a cognitive process, categorized into four dimensions: (1) factual knowledge, (2) conceptual knowledge, (3) procedural knowledge, and (4) metacognitive knowledge (Table[● 6]). Interestingly, students discovered a link between their own learning in research and design work and discipline-based knowledge. They reflected on *"metacognitive knowledge"* as *"knowledge of cognition in general as well as awareness and knowledge of one's own cognition"* (Fig[● 15]).



Fig[● 15] Comment on the cognitive knowledge when dealing with complexity (ISP2, Day 4, Group 2).

Knowledge taxonomy according to Krathwohl (2002) added to the discussion on individual and general learning (Table[● 6]). As students correctly pointed out, work in complex multidisciplinary built environments emphasize the assessment of learning. Education plays an important role in shaping building cultures. The challenges are linked to complex issues addressed by research but also new trends like digitalization and tools bringing new ways of approaching knowledge. The awareness of content, context, and knowledge of cognition should be an elementary part of contemporary cross-disciplinary education in complex built environments.

A. Factual Knowledge – The basic elements that students must know to be acquainted with a discipline or solve problems in it.
- **Aa. Knowledge of terminology**
- **Ab. Knowledge of specific details and elements**

B. Conceptual Knowledge – The interrelationships among the basic elements within a larger structure that enable them to function together.
- **Ba. Knowledge of classifications and categories**
- **Bb. Knowledge of principles and generalizations**
- **Bc. Knowledge of theories, models, and structures**

C. Procedural Knowledge – How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.
- **Ca. Knowledge of subject-specific skills and algorithms**
- **Cb. Knowledge of subject-specific techniques and methods**
- **Cc. Knowledge of criteria for determining when to use appropriate procedures**

D. Metacognitive Knowledge – Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.
- **Da. Strategic knowledge**
- **Db. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge**
- **Dc. Self-knowledge**

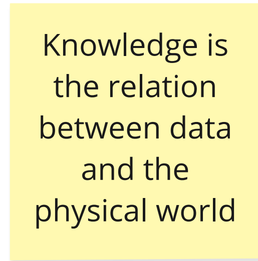
Table [● 6] Structure of knowledge dimension of the revised taxonomy (Krathwohl, 2002)

Another example was the scope of different forms of knowledge represented by different participants in the process of decision-making and inter-/transdisciplinary projects. Depending on the pedagogical curriculum of the school and program in the built environment, students from early education can learn how to integrate different forms of knowledge in projects by reflecting on the interplay of actors in the real world. They learn how to integrate knowledge from different disciplines (expert knowledge), from civil servants and decision-makers (institutional/bureaucratic knowledge) and stakeholders (stakeholders' knowledge). According to Bunders et al. (2010), this integration of different forms of knowledge in decision-making processes requires in parallel organizational and social integration, communicative integration and technical integration. If students work in application projects outside their own discipline and linked to stakeholders outside academia, they may have an opportunity to learn about different methods, processes and instruments to develop knowledge and understand the challenges. This inter-/transdisciplinary knowledge construction demands from students to learn skills and accommodate values in a context of complex built environment and sustainability in decision-making.

4.4 Future demand of knowledge and digitalization

Reflecting on research question 4 in relation to BuildDigiCraft

Students identified a demand of knowledge as a need for better know-how and a need to recognize future conditions that are not always presently known. It was easy to see from the group studies that "digitalization," "automation" and "data analysis" are clear examples of understanding that technology in the future may help to solve current issues or simply enhance current knowledge. Fig[● 16] shows one student's approach to knowledge seen as related to a large extent on available data. A conclusion was that it was a narrow but popular way of perceiving the physical world through the analyzed available data. In this respect the knowledge gap lay in a lack of data and the future demand for knowledge will depend to a large extent on reliable sources of data.

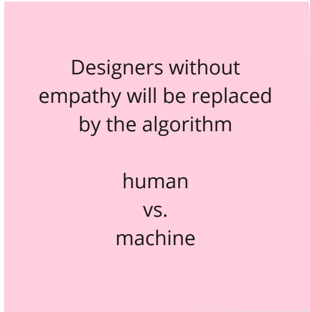


Fig[● 16] What is Knowledge? (Source: students' work at the Workshop ISP2, Day 4: Knowledge, Group 2).

Artificial intelligence, for example, can analyze the current collected data from various perspectives. This includes the possibility of filling in the gaps in data that might otherwise obscure the creation of meaningful new knowledge. Automation as a key part in data analysis helped to introduce new data at any given moment and therefore carried out integrated analysis to get better perspectives on current knowledge. Still, a question was raised of knowledge gaps that need to be addressed first by humans before relying completely on digital tools. The student asked: *"Will AI make sense of what we don't understand?"* (ISP2, Day 4: Knowledge, Group 3).

In the analysis of the **BuildDigiCraft** project, material was mainly seen as "knowledge reuse" and "new materiality" sub-topics. But also how the physical world could be described or accounted for in a digital world to help to design better products for the future. Examples of knowledge reuse that emerged from analysing the project included the reuse of materials and how more sustainable materials can be used in future. Sustainability itself could be defined through various aspects (environmental, social, economic) that would be valued more in future than those currently. This knowledge might change, especially through various knowledge transfer processes (individual > organizational) which simply takes time when we see it at different scales (local, global scales). In addition to "reuse," students argued that the future demand of knowledge might help to develop better materials that can originate from extensive analyses from current knowledge (as elaborated in the previous section), due to the fact that knowledge gaps can be filled with fresh data.

Development of artificial intelligence, computer learning, algorithms applied in the built environment raised a question about future knowledge demands, ethics and the role of the designer in securing qualities in future relations *"human vs. machine"* (Fig[● 17]).



Fig[● 17] *Human vs. machine* (Source: students' work at the workshop ISP2, day 4: Knowledge, Group 3).

As a reflection from the material referring to "Knowledge production," the future demand of knowledge would need to address the growing complexity of topics rooted in an urbanized world better, along with the decision-making and ambition to respond to urgent issues within a framework of sustainability, regeneration, efficiency, resilience as well as socially consensual and negotiated knowledge production and co-production.

Another perspective on the future demand of knowledge was to address contemporary problems and questions rooted in society, behaviors, and quality of life. Trends showed that there was a changing paradigm in how knowledge production was held due to growing demand and use of digital technologies. New opportunities were observed that were emerging in knowledge production of future building cultures that may lead to greater use and dependence on the virtual world and AI.

4.5 Knowledge and the design profession in the digital era

Preparatory input and lecture by
Claes Caldenby, Professor emeritus at Chalmers

"We are in the midst of a tremendous social and economic transformation, as sweeping in its impact as the Industrial Revolution was some 150 to 200 years ago" (Fisher, 2000).

The changes around the turn of the millennium have been described by many and been given different labels: post-industrialism, globalization, information revolution, network society, world of flows. It is all too easy to get lost in the midst of all the overwhelming opportunities and threats. The longer historical perspective could however, it could be argued, give a structure to the changes that offer us some clues about how to handle them.

Techne is a Greek word for knowledge, often used in the sense of the craftsman's practical knowledge of making things. Techne is obviously the knowledge of the technician but traditionally it is also the knowledge of the artist. Art and technology were one and the same in pre-modern, pre-industrial societies. With modernization and industrialization, they begin to go their separate ways, ending up being each other's opposites: the spontaneous artist versus the rational engineer. Today, they seem to be merging again with computer technology as a design tool (Liedman, 1997). A new concept of techne could be understood to combine the knowledge of the artist with that of the technician. The tasks put to us in a *"world of flows"* could be described as *"from an urge to dominate nature to one that seeks balance with it; from mass production to mass customization; from large bureaucratic organizations to smaller project-based operations; from specialized jobs to versatility; and from professional autonomy to participatory teamwork"* (Fisher, 2000). There is a possible flipside to the project-based operations and the versatility in loss of long-term job security that must be dealt with. But basically, this is an optimistic view of the role of the designer in a world constituted by "fuzzy" problems. This could even, somewhat provocatively, be stated as a belief "that design may have as central a place in a world of flows as science and technology had in the industrial revolution." Here again we could see the designer combining the roles of artist and technician.

Essential in this development is the trust in and pride of one's own work as a professional. New Public Management has meant a transfer of control from professionals to economists and politicians and *"a world domination of the petty"* (Bornemark, 2018). *"Evidence-based design"* is important but not always the right answer to fuzzy problems. It seems more to belong to an industrial society than to a world of flows which arguably should celebrate the knowledge of the designer. Again, we could return to the craftsman's practical knowledge. The craftsman is not only the skilled manual laborer who disappeared with industrialization. The value of good craftsmanship is important for the computer programmer, the doctor, the parent, the citizen as well as for the designer. Pride in one's work includes reflection in and on the making (Sennett, 2008).

Qualities of craftsmanship that need to be sustained in the digital era:[1]

1. Materiality (being real not virtual)
2. Location (being grounded)
3. Sustainability (being adapted to nature)
4. Diligence (being passive and professional)
5. Openness (being vague)
6. Good life (being human)

[1] (Source: lecture by Claes Caldenby in the project **BuildDigiCraft**: *"Craft in a Digital Era. A Search for Earthly Paradise?"*: https://www.youtube.com/watch?v=pLL1ZR5Uvk0

4.6 Connection to the Davos Declaration

"There is an urgent need for a holistic, culture-centred approach to build environment and for a humanistic view of the way we collectively shape the places we live in and the legacy we leave behind."

(**Davos Declaration**, 2018, *"The central role of culture in the build environment,"* §3)

The Davos Declaration (2018) stresses the central role of culture for the quality of the built environment and incorporates all activities with spatial impact, from craftsmanship details to large-scale urban planning and development of landscapes. "The Davos Baukultur Quality System" (2021) is a contribution to the ongoing Davos process and proposes eight criteria for making the evidence-based assessment of the Baukultur quality of places. These criteria include governance, functionality, environment, economy, diversity, context, sense of place and beauty.

The connection to the Davos Declaration in the **BuildDigiCraft** project is in the sense that knowledge production, transfer, sharing for high-quality places in both the built environment and open landscapes is essential for education. This knowledge can help cultures to consider and recognize preconditions and challenges, it can help to raise awareness about past, present and future values. The importance of knowledge production, management, exchange in the field of Baukultur for the quality of the built environment, stresses the central role of culture in the context of all activities trained by students in higher education. These activities require gaining individual knowledge about inventory, design, planning and construction, as well as knowledge democracy for cross-disciplinary discourse and through multi-level and cross-sectoral cooperation between different actors, participation of civil society, and an informed public.

Evidence-based learning is only a part of knowledge generation in higher education; the other involves individual learning.

In reference to Jonna Bornemark:

In the knowledge transfer process, knowledge has to be redeveloped by each individual (Dan Paulin and Kaj Suneson, 2011). Consequently, the knowledge barrier cannot be overcome simply by providing access to a knowledge repository. In this case, a distinction is made between information and knowledge if the information is an objective unit that is presented to the person. Whether an individual will transform it into knowledge depends on a number of factors such as previous experience, background and "sense-making." The important factor is the choice of methods used in the process of knowledge transfer. Breaking down hierarchies enables knowledge transfer, where the development of horizontal communication flows promotes the efficiency of the process. As the complexity of today's challenges often requires interdisciplinary research and solutions, the inclusion of the principle of multidisciplinary promises to provide the necessary competencies.

The concept of high-quality *Baukultur* manifests itself in a multidisciplinary approach, encompassing notions such as built environment, cultural heritage, quality of life, social cohesion, well-being, resilience and others. The impact factors, the areas affected and the people involved form a complex set of units, the development into a holistic targeted system of which is directly linked to the transfer of knowledge in a multidisciplinary environment. Principles defined for successful knowledge transfer – i.e., the provision of the horizontal flow of information, the rating and feedback, the time resource factor – can form the basis of an approach to building a high-quality Baukultur process.

Project results show that concepts of knowledge and approaches to knowledge production, management, transfer/exchange or sharing are diversely represented in the academic, institutional, expert, public and individual discourse. Reviewed material from the project confirms the diversity of aims, questions, methods and tools applied to address socially relevant important issues raised in the students' projects.

Despite the different topics and methodology, students chose to work with the high complexity of problems. There are common "red threads" when analyzing knowledge in relation to Baukultur in higher education. First, the importance of knowing more and/or exploring the craft, art/design and digitalization in the diverse context of the built environment. This is often to gain new skills in connection with the rapid development of new digital tools for design and production. Others are to share common values like ethics and knowledge democracy, to apply knowledge and approach multi-actor society, aiming for the quality of the space and sustainable lifestyle in the built environment.

Finally, there is an "education" component, which plays an important role in how knowledge is generated and enhanced under future conditions – especially how the educational system must change in the digital age. This is an open question and depends heavily on the afore-mentioned components, like on how to minimize knowledge gaps where physical and digital worlds are seen to be merging closer together than ever before.

5.0 Final reflections and guidelines

The results from the **BuildDigiCraft** project show that the complex concept of knowledge related to the shaping of built environment has evolved meaningfully due to the necessity of rethinking the role of science and its relationship to society and building cultures. This was due to serious challenges involved in achieving sustainable development, when science faced growing complexity of real-world problems, social relevance and the demand for collaboration between academic and non-academic actors, research questions going beyond one discipline. A new social distribution of knowledge is occurring as a wider range of organizations and stakeholders contribute skills and expertise to problem-solving.

Results from the project show that knowledge production and management in higher education can support transfer and creation of cultural values expressed in the Davos Declaration and includes the contribution of universities to educate students toward the vision of high-quality Baukultur. This involves learning how to apply conscious and well-debated design, maintain and improve the qualities of places by construction, build social cohesion, promote environmental sustainability or maintain and protect our cultural heritage. Eight quality criteria proposed in the Davos Baukultur Quality System derived from the Davos Declaration highlights important aspects of shaping built environment linked to governance, functionality, environment, economy, diversity, spatial context, sense of place and sense of high quality responding to the human need for beauty. The teaching curriculum in higher education needs to address these; education and research should train future professionals and designers how to integrate best practices and applied knowledge (implicit knowledge) into documented and written means (explicit knowledge) for a high-quality Baukultur:

- Shifting the focus from preservation of knowledge to its dissemination via education. For high-quality Baukultur it is necessary to create and grow learning communities. Higher education plays a vital role in active participation in community-based learning, being driven by the recognition that the most valuable knowledge in any group or organization in the society is "tacit" and that people need to share their knowledge and collectively bring their intelligence to bear to solve important problems.

- Knowledge democracy should be safeguarded – it is necessary to provide conditions that allow dominant and non-dominant actors to have equal access and ability to bring this knowledge forward to contribute to solutions for societal problems (self-referential knowledge production, knowledge dissemination, mutual learning for knowledge production between scientists and societal actors' style, knowledge co-creation between scientists and societal actors).

"A place is determined by Governance, based on participatory democracy with good processes and management of places. Diversity ensures vibrancy and social inclusion."

(**Governance & Diversity: Davos Baukultur Quality System**, 2021).

- The inter-/transdisciplinary approach involves a diverse range of specialists, academics and non-academics and therefore creates opportunities for self-referential knowledge and production style. Recognizing human needs and purposes should involve individual and unique approaches to knowledge production. For example, transdisciplinarity in architectural or urban design involves ethics, aesthetics and creativity inside of disciplinary and professional work, incorporated with social and political, normative and ethical questions. It contextualizes and repositions both theory and learning, including the understanding of everyday people. This requires an "in-practice model" of design and learning, greater relationality of knowledge today, which in turn requires a collaboration among a mix of actors.

"Functionality addresses the level of satisfaction of human needs and purposes."

(**Functionality: Davos Baukultur Quality System**, 2021.)

- Research and education within higher education contributes to decision-making, development projects, planning, design or construction to solve/address existing problems within a framework of sustainability, regeneration, efficiency, resilience, even affordability and vitality. It should involve the generation, exchange and use of cross-disciplinary knowledge.

"Respect for the natural Environment with mitigation of climate change contributes to the sustainability of a place. Economy with long lifecycles and long-term viability of places is an important component of Baukultur quality.

(**Environment and Economy: Davos Baukultur Quality System**, 2021.)

- Academia is open for collaboration and knowledge production within society. It has been acknowledged that not only new knowledge but also skills are indirectly produced and disseminated in conversations and networking activities. Context and sense of place should involve more than evidence records about the places (explicit knowledge), but rather demand collection and sharing of the memories or stories people tell about places or implicit knowledge in applied best practices. Therefore, one way to help people share and internalize tacit knowledge is to allow them to talk about their experiences and to exchange their knowledge while working on specific problems.

"The particular spatial Context of a place with its physical and temporal characteristics, such as the shape and design of buildings, neighbourhoods, villages and landscapes and respect for built heritage has a great impact on the quality of a place. A specific Sense of place is created through social fabric, history, memories, colours, and odours of a place producing its identity and the attachment of people to it."

(**Context & Sense of place: Davos Baukultur Quality System**, 2021.)

- Education about high-quality built environment with regards to making places needs to contextualize and reposition both theory (explicit knowledge) and learning (tacit, implicit knowledge), aesthetics and understanding of needs of everyday people.

"Places of high quality are authentic and respond to the human need for Beauty."

(**Beauty: Davos Baukultur Quality System**, 2021).

Results from the project show that today the university in the up-to-date complex environment of information transfer plays a role as "**knowledge hub**," animating indigenous development and innovation spanning between industry, government, and society. The contemporary role of academia has changed as it serves as a facilitator of emerging modes of learning, knowledge production and knowledge exchange. The new role of universities is to advance technological innovation and economic development.

The role and purpose of higher education has increasingly come to be the preparation of young people across society to take on highly skilled positions in industry and society.

The perspectives on knowledge production have evolved a lot, especially over the last decades when science faced growing demands for collaboration between researchers, new research questions going beyond one discipline. Here more than ever, collaborating communities, researchers and decision-makers seek to tackle problems that require both specialized knowledge and integrative skills to cope with complexity.

Knowledge and skills are key human capital elements of building sustainable environment. This project guides and reflects on the important role of higher education in preparing the future generation of designers to take responsibility for shaping high-quality built environment, sharing knowledge and values of good craftsmanship. Moreover, exemplified results from the project show that in the age of digitalization and globalization, there is an opportunity to use a wide set of digital tools for knowledge production and exchange.

1. In higher education, individuals should learn to grow in one's own work as professionals. Education and research should be directed toward how we can prepare individuals to grow in all of **Aristotle's three categories of knowledge** – episteme (scientific knowledge), techne (knowledge of craft) and phronesis (ethical knowledge). "Evidence-based design" is important but not always the right answer to wicked design problems in the built environment. The knowledge of the designer needs training to learn and implement the craftsman's practical knowledge: *techne* and evidence-based assessment related to *episteme*. Evidence-based learning is only a part of knowledge generation in higher education – the other involves individual learning.
2. The ultimate goal of the university is to create opportunities for students to make **informed design decisions** and **explore phenomena-based knowledge**. This includes learning about cultural values like the history of architecture and built environment (old and contemporary), humanistic understanding of design questions, state of the art and an awareness that every problem is unique involving

phronesis. Students reflected on the "metacognitive knowledge" (Krathwohl, 2002) and learning to gain knowledge of general cognition as well as self-knowledge and awareness.

3. High-performing higher education institutions are those that effectively advance, distribute, and recombine tacit knowledge. The current role of the university as a facilitator of emerging modes of learning, knowledge production and information transfer embody the necessity to combine **all types of knowledge: explicit, implicit and tacit** into the formal, semi-formal, and non-formal tools of education, including the shift from teaching to learning. There is much explicit knowledge found in codes, publications embedded within people and organizations. Still, the majority of knowledge regarding built environment, including construction, is tacit or implicit. In academia, explicit knowledge in form of data, records, and documents (present in journal publications, databases, books, websites, and videos) is relatively easy to disseminate. On the contrary, tacit knowledge is difficult to transfer by means of writing or speaking. It is embedded in people, organizations, societies, and cultures. It comes from experience, thinking, competence and commitment. In academia, tacit knowledge can be found in workshops, conference discussions, internships, and exchanges.

4. Universities play an important role in the **generation and dissemination of knowledge** in the process of learning. Students need to be trained in understanding and making the complex and massive knowledge explicit that is required for professional practice and identifying ways in which this knowledge can best be initially learnt and developed further throughout professional life. Understanding how learning experiences and educational processes might best be aligned or integrated to support professional learning is to let students learn how to exchange knowledge from one type to another. This is referred to as **knowledge conversion** and knowledge transfer. Students can study to externalize knowledge communicated to spoken or written form, supporting knowledge conversion from tacit/implicit to explicit. Here, students learn to reconfigure existing knowledge inside and outside university in connection with the rapid development of new digital tools for design and production. This calls for training selective approaches to gather data, information and knowledge.

5. From early education onwards, students need to train creativity and develop **skills to communicate design work**. ISPs presented different research ideas and approaches to design where thematic group work and discussion panels created opportunities for students to present their work. Activities promoted in academia, such as workshops, public presentations and competitions, allow students to learn from each other and develop skills of creativity, argumentation, and communication.

6. **Practice-based learning** is used in higher education and enables theory–practice bridging there. An engineering curriculum represents the "epistemic transition" from the natural (and mathematical) sciences to the engineering sciences through to the sciences of design and the practice of application. Students can gain new knowledge in practice, while working and collaborating with professionals in practice. Practice-based knowledge is recognized to be personal, disputed, conditional, and dependent on individual meaning-making, when often university traditions have built on the assumption that knowledge exists as discrete facts developed, distributed, and institutionalized in good research by expert authorities.

7. Education and research play an essential role in the information transfer **fostering innovation** in a particular sector or interest area. Sharing different types of knowledge in higher education can be carried out with the help of effective involvement of interested sides in the educational process – municipalities, communities, non-governmental organizations (NGOs), and other actors in society. Students from the early stage of studies up to the advanced level of education gradually learn to select the appropriate tools and integrate different

forms of knowledge into the study and research projects. They learn to reflect on the interests of various actors in multidisciplinary projects and evaluate the challenges of the decision-making process.

8. Digitalization may create opportunities for knowledge generation and exchange. The advent of the Internet has become one of the reasons why a lot of face-to-face universities started developing online courses. By encouraging the formation of **virtual learning communities**, face-to-face universities can create a competitive sustainable advantage for themselves, the same as benefiting from using digital tools for knowledge production and sharing – this should be the way forward in the 21st century. Since the opportunities for face-to-face interactions are rather limited in universities of today (e.g., pandemic due to COVID19, 2020–2021), virtual learning communities supported by Internet technologies are viable alternatives to live conversations and knowledge exchange.

9. Digitalization enables developing new skills working with the complexity of data in the built environment and can provide **efficient digital tools** for seeking new research issues. Digital tools allow collecting large amounts of qualitative data and working with different data sets. By merging data from several qualitative studies (meta-data), research is able to pose questions that individual projects cannot raise.

10. Results from the project show that knowledge production in the digital era can be tacit and in architecture is often linked to the seamlessly produced **virtual "experience"** rather than just artefacts. Tacit knowledge is non-articulated and experience-based knowledge linked to best practices and making. It is the application of implicit knowledge specific to a student's needs. The modern world is constantly providing us with new challenges, though, and to meet these challenges, we need conscious methods for evaluating knowledge and experience. Due to growing complexity and digitalization in disciplines involved in shaping built environment, digital technology (software of immaterial design with immaterial making) is eliminating the separation between design and the making. Here, students have been turning to software developed for other fields. Digital workflows can re-engage craftsmanship and connect **design intelligence with material intelligence**.

11. There is a necessity of re-identification of the designer's work with the work of a craftsperson in the digital era. Digitalization highlights the importance of data and evidence-based knowledge, where the experience and place-based work of the designer needs to be promoted. In **the digital era the qualities of craftsmanship** that need to be sustained should include: *"Materiality"* (being real, not virtual), *"Location"* (being grounded), *"Sustainability"* (being adapted to nature), *"Diligence"* (being passive and professional), *"Openness"* (being vague), *"Good life"* (being human).[2]

[2] (Source: lecture by Claes Caldenby in the project **BuildDigiCraft**: *"Craft in a Digital Era. A Search for Earthly Paradise?"*: https://www.youtube.com/watch?v=pLL1ZR5Uvk0

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