EUROfusion Knowledge Management Strategy

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The EUROfusion General Assembly unanimously endorsed the EUROfusion Knowledge Management Strategy on 12 December 2023 proposed for the remaining years of the Horizon Europe Framework Programme 9 (FP9).

Send feedback or suggestions to KM_strategy@euro-fusion.org

Executive Summary

The capture and transfer of tacit knowledge is vital in highly technical, scientific and research-driven sectors such as nuclear fusion research. Benefits of effective knowledge management include:

- **Risk mitigation:** safeguard critical knowledge by preventing its loss due to retirements, job transitions to outside EUROfusion and natural erosion of memory over time.
- **Synthesis of knowledge**: integrate know-how and experience from diverse teams to identify underlying physics and engineering principles, distil best practices and lessons learned.
- **Efficiency increase**: embed knowledge capture and transfer into everyday processes, make knowledge accessible and encourage its reuse.
- **Active prevention of similar issues and faults:** avoid repetition of similar errors by implementing insights gained from other facilities and past experiences. Incorporate lessons learned and best practices into engineering design, operational procedures and commissioning of plant systems.
- **Learning and development support:** improve training and education opportunities and materials fostering continuous learning and skill enhancement.
- **Leverage collective expertise as competitive advantage:** capitalize on the collective knowledge of EUROfusion as a strategic advantage in building external collaborations.

The objective of the EUROfusion Knowledge Management Strategy is to establish effective knowledge management activities to ensure tacit and explicit knowledge is managed strategically and efficiently, aligned with the needs and goals of the EUROfusion Consortium delivering value to the member organisations and internal/external stakeholders. Incorporating suitable processes and governance, the strategy aims to develop an educated and well trained workforce while cultivating a European fusion community that shares experience and supports each other.

The EUROfusion Knowledge Management Strategy is based on a four-pillar model, namely converting tacit to explicit knowledge (knowledge capture), tacit to tacit knowledge transfer between experts (community building), building tacit knowledge (training and education) and finally ensuring knowledge is accessible and used (tools and accessibility).

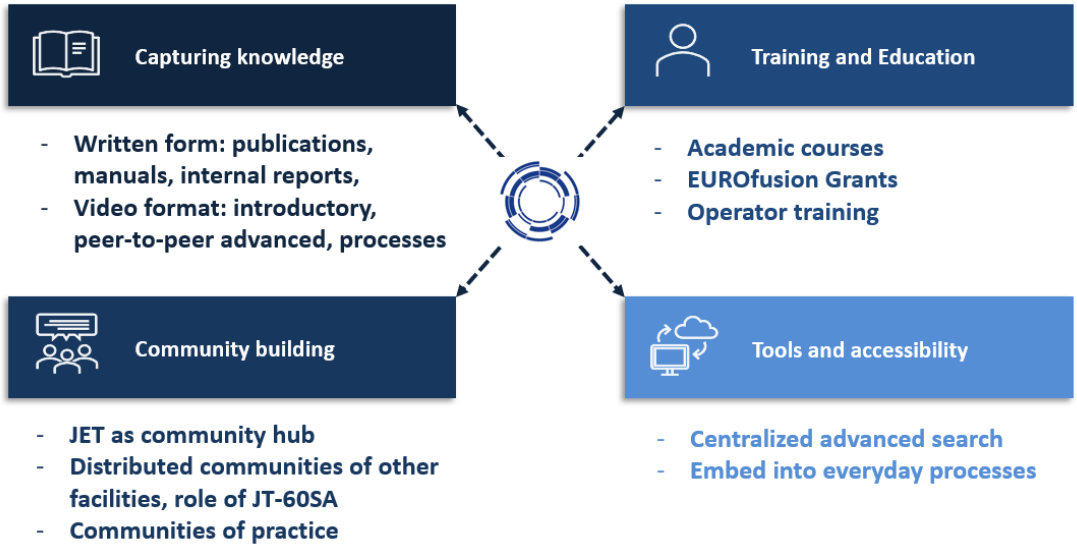


Figure 1 *– The four pillars and elements of the EUROfusion Knowledge Management Framework*

The strategy identifies 25 strategy elements to be considered in the EUROfusion Knowledge Management Implementation Plan that will be further developed for 2024-25 following feedback from the EUROfusion General Assembly (December 2023).

Table of Contents

I. Introduction

The EUROfusion knowledge management (KM) strategy focuses on the capture, codification, and transfer of tacit knowledge of EUROfusion experts. The conversion of tacit knowledge into explicit knowledge enables further knowledge sharing and transfer between experts.

What is knowledge?
Knowledge is information in action. It is created, can be captured or shared, but has to be accessible in order to reuse, adapt or adopt it to similar or new situations.

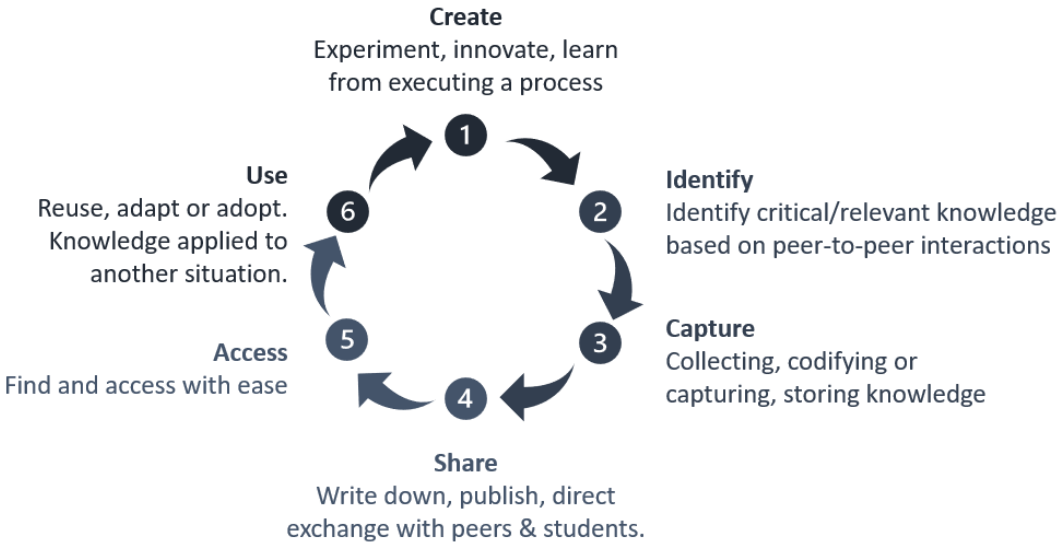


Figure 2 *– The knowledge management flow*

What is tacit knowledge?
Tacit knowledge is experience, intuition, know-how and skill gained over time leading to competence. It is harder to articulate and transfer than documented information called explicit knowledge.

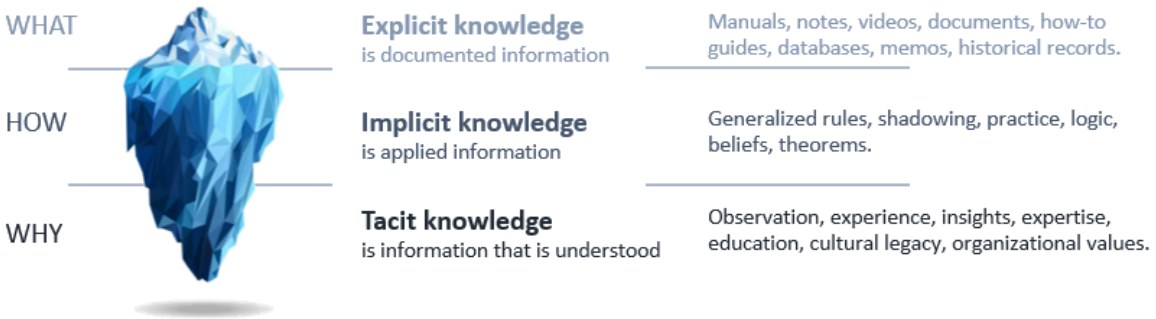


Figure 3 *– Difference between tacit, implicit and explicit knowledge*

Use case 1: *A person attempting to do a process for the first time(s) (e.g. run a simulation code or commission a tokamak system) can learn from* ***explicit knowledge*** *documented in manuals and publications. However, this person would greatly benefit by talking to an expert who has done the process before tapping into their* ***tacit knowledge*** *involving best practices, lessons learned with common and rare failures to avoid.*

What is knowledge management?

The knowledge management connects people to people, and people to content using **systematic approaches to enable knowledge and information to grow, flow and create value** (APQC definition). Without dedicated processes and enablers, tacit knowledge tends to be lost. Approaches are fragmented depending on the needs of the organisation. Common approaches however often include a selection of

- communities, expert registers, technical mentoring,
- knowledge transfer, knowledge capture, best practices, lessons learned, and
- content management.

EUROfusion as a knowledge management organization

A core function of the EUROfusion Consortium activities is knowledge management, including creation of knowledge through scientific exploitation, codification of the knowledge to publications, knowledge sharing through project / task force meetings and conferences, and complementing academic training through the EUROfusion grants, summer/winter schools and other educational activities. To assess the status of the current EUROfusion knowledge management activities and develop a new strategy, the NASA knowledge reapplication model (E. Rogers, M. Ryschkewitsch, 2008, Knowledge Reapplication: Enhancing Organization Learning at NASA) is adapted to the characteristics and needs of the fusion community.

The **EUROfusion Knowledge Management Framework** establishes four fundamental pillars for knowledge management, converting tacit to explicit knowledge (knowledge capture), tacit to tacit knowledge transfer between experts (community building), building tacit knowledge (training and education) and finally ensuring knowledge is accessible and used (tools and accessibility).

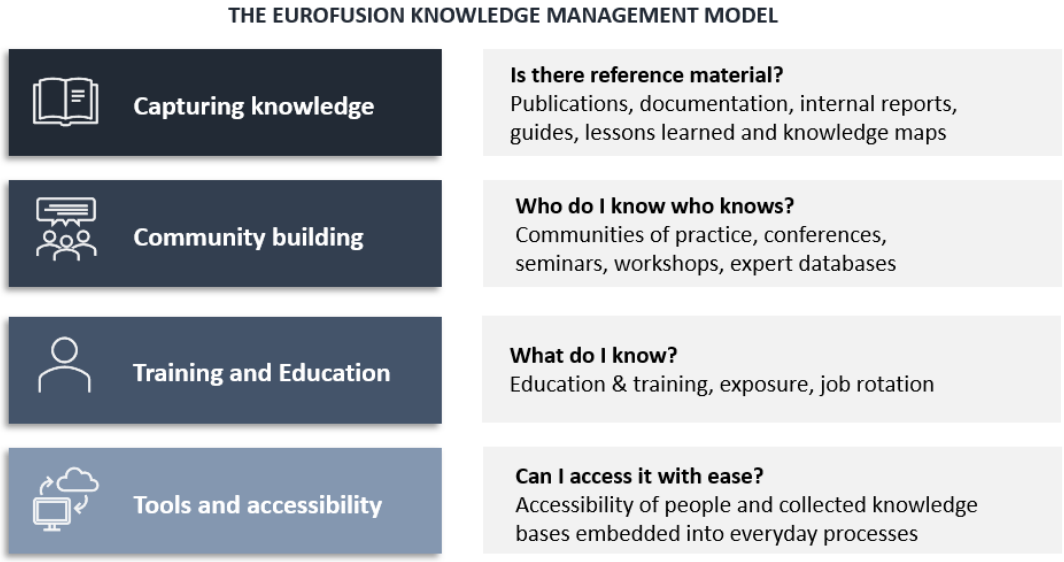


***Figure 4** – The four pillars of the EUROfusion Knowledge Management Framework*

***Use case 2.** An expert has a question requiring tacit knowledge (e.g. resolve an issue with a tokamak scenario in the control room, recurring fault on a plant system). First the expert will attempt to solve it using their own training and experience. Secondly, they will identify colleague(s) who have more experience on the topic and contact them. The colleague might be able to help or point them to written material to consult. Thirdly, they will search for available material (written or visual) to consult and learn from. In both the second and third case, it is vital to have quick and efficient access to the right people and material. In the best case, access to knowledge is embedded in the system used offering the right contract person and/or relevant material automatically.*

Preparation of the knowledge management strategy

The EUROfusion Knowledge Management Strategy has been prepared based on stakeholder interviews including the members of the extended management meeting of the EUROfusion Programme Management Unit, Work Package Leaders in the EUROfusion Fusion Science and Fusion Technology Departments, selected EUROfusion experts as well as external stakeholders from Fusion for Energy (F4E) and the ITER Organisation. The Training and Education Office offered an information session in October 2023 for any EUROfusion expert to join and discuss their needs, difficulties, opportunities, and ideas.

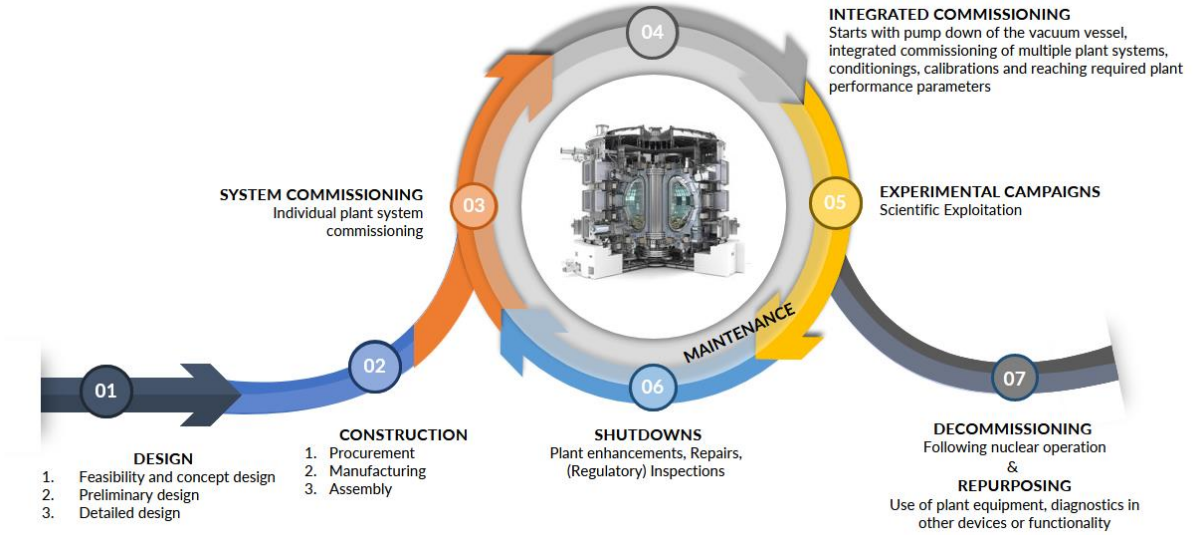


Figure 5 *– Fusion product lifecycle*

Status of knowledge management activities in EUROfusion

Knowledge management activities are assessed on three main areas of fusion research defined as following based on the fusion product lifecycle (figure 5):

- **Physics**: scientific exploitation through experimentation, theory, or numerical simulations.
  -> Physics exploitation in phase 5 (campaigns) in the fusion product lifecycle.
- **Engineering:** technical design, manufacturing and installation of fusion systems and safety.
  -> Phase 1 (design), 2 (construction) and 6 (enhancements) in the fusion product lifecycle.
- **Operations**: (first) system and integrated commissioning, daily operation, maintenance, fault identification and recovery. For the purposes of this report, decommissioning and repurposing is handled jointly with Operations.
  -> Phase 3 (system commissioning), 4 (integrated commissioning), 5 (campaign operation), Maintenance and 7 (decommissioning) in the fusion product lifecycle.

The assessment of the current status of knowledge management activities related to physics exploitation, engineering and operation of fusion devices has been summarized in the table 1 based on the stakeholder interviews in relation to the four pillars of the EUROfusion Knowledge Management Framework (figure 4). High, medium, and low indicates the level of knowledge management activities in each of the categories.

The assessment supported the identification of needs and priorities to be addressed in the development of the EUROfusion Knowledge Management Strategy. A majority of the recommendations will focus on Operations (low) and Engineering (medium), two areas with heavy reliance on tacit knowledge. This is aligned with the priorities of DEMO development and supporting preparation and execution of ITER operations (as ITER is currently in phase 2 construction and 3 system commissioning in the fusion product lifecycle).

Table 1 – Assessment of the status of Knowledge Management Activities in EUROfusion

Areas	Physics	Operations	Engineering
1. Captured material: Publications, theses, internal reports, documentation, guides	**High activity level** Publications, PhD theses, internal reports	**Low activity level** Commissioning & operating procedures.	**Medium activity level** Publications, documentation, theses, internal reports.
2. Community building: Conferences, missions, workshops, seminars	**High activity level** Visits to different devices, conferences.	**Low activity level** ITER Operations Network, EUROfusion Operations Network	**Medium activity level** Conferences, visits, dedicated meetings
3. Training and Education: Availability of courses, textbooks, summer schools.	**High activity level** Multiple textbooks, courses, and schools.	**Low activity level** No dedicated course, textbook, or school. Learned on the job.	**Medium activity level** ~2 textbooks, 1-2 schools, limited set of courses.
4. Tools and accessibility	**Medium activity level** Pinboard, IDM and JET document archive search function. Manual finding of information and documents.		

Scope of this document

This document describes the EUROfusion Knowledge Management Strategy focusing on short-term recommendations that can be carried out within the European Horizon Europe Framework Programme FP9. The recommendations are based on the core principles listed below.

The **core principles** underlying the recommended strategies and activities are:

- **Unity**: Work jointly with interested beneficiaries and affiliated entities.
- **Collaboration**: Engage and collaborate with external partners (Fusion for Energy, QST, ITER, …)
- **Inclusion and trans-generational effort**: Ensure activities are inclusive, open to all EUROfusion experts to participate and benefit from. Connect different generations through activities such as communities of practice, technical mentoring, knowledge transfer seminars and capturing knowledge during transfer to video and written form.
- **Accessibility**: Activities, where possible, can be accessed remotely. Include supporting features (e.g. video recording, transcription) to overcome language barriers.
- **Diversity**: Target diverse audience with different learning and work capabilities and styles.
- **Test and optimise**: Start with a few targeted pilot projects, learn from the experience, optimise and expand in a step-by-step manner. Aim for targeted (specific focus) and tangible results.

This document does not cover the data, document, information nor the communication management strategy. Please refer to the relevant documents (e.g. data management plan) for these.

II. Application of the EUROfusion Knowledge Management Framework

2.1 Capture knowledge

The most traditional element of knowledge capture is the conversion of tacit knowledge to explicit knowledge, that is to codify knowledge into storable content, written documents, or video so it can be accessed anytime in the future. This helps synthetize knowledge into best practices, lessons learned as well as identify underlying connections and concepts. It contributes to knowledge retention thereby mitigating risk against experts leaving (to industry, private companies, retiring) or forgetting details over time.

- **Pros:** long-term solution if it exists, mostly synthetised know-how
- **Cons:** significant effort and time commitment of the expert, relies on tools to make it accessible and potentially experts to provide context or missing information.

Knowledge capture in publications, and theses
Traditionally knowledge is codified into publication in refereed journals. EUROfusion provides a pinboard as repository of planned EUROfusion publications facilitating their approval before submission to journals. The EUROfusion pre-print server offers public access to accepted publications. In FP9 there were a significant number of publications on physics (NF, PPCF, PoP = 2000) and engineering (FED, RSI = 1497) topics.

Tacit knowledge, e.g. on the engineering design, commissioning and operation of fusion devices including reasons behind decisions, lessons learned are rarely published or shared. To support publications on operational experience, PPCF has opened a Special Issue on the Physics and Engineering of Toroidal Fusion Plasma Operations.

Example 1 *– UKAEA has submitted 5 papers in 2023 to the PPCF special issue on operations on the JET DT operational experience sharing the challenges, issues and decisions related to operation with tritium. The authors were provided additional support, monthly discussion forums on what elements to include and a technical writer to ensure all concepts were introduced in a linear fashion. The key challenges are what to include, and how to introduce the topics that are embedded into complex systems and need significant background knowledge of the systems.*

Knowledge capture in internal reports
EUROfusion reports (including reports, engineering documents from the Fusion Technology Department) are stored on the Integrated Document Management System (IDM).

Knowledge capture in presentations
Presentation slides are stored on the EUROfusion Pinboard, Indico platform or the wiki pages. These can provide a reminder on the information shared in presentation but can be difficult to fully benefit from without the information provided by the speakers.

Knowledge capture in logs
Knowledge capture works best if it is embedded into everyday processes, e.g. in the form of logs coupled with a review highlighting key insights, lessons learned and best practices post-mortem.

- Good personal note taking practices can offer a multitude of information and facts that can support the author for later reporting and sharing their experiences and know-how. It can also support colleagues reviewing the activity at a later date.
- Centralized logs: Logging requires buy-in from the users and strong senior management support. Its accessibility relies on suitable metadata structure.

Synthesize best practices and lessons learned from the logs and activities.

Example 2 - JET had an extensive logging system partially due to reporting requirements to the European Commission. This included a control room log (jotter) for each scientific and engineering role include pre- and post-session notes, pre-pulse setup and post-pulse analysis all linked jointly under the sessions and pulse numbers. The JET delay logs (any delay over ~10 minutes written by the Engineer-in-Charge) ensured all issues were recorded and reviewed as well as providing overview of common and unique faults. Finally, the pulse termination analysis provided a timeline of all stops including their trigger, limit and reaction.

Knowledge capture using video

Interviewing experts is often attempted at first to capture tacit knowledge. The experience shows that it provides little value unless it is meticulously prepared based on the needs / questions of the community. Instead, more value can be provided by capturing knowledge transfer in progress by:

- Introductory level – record training sessions, EUROfusion Science Meetings, prepare dedicated introductory videos when needs and audience is clarified.
- Advanced level (peer-to-peer) – organise peer-to-peer workshops to share experience, lessons learned, best practices with opportunity from the community (similar experts from other devices) to ask questions and direct the topics based on their needs.
- Advanced level (individual) – ask the community (similar experts at other facilities) what their questions and key know-how are to record. In case of unique aspects (e.g. processes and systems required by JET's complexity, size and high plasma current) review with expert panel what information to capture.
- Record processes – a complimentary visual element is often useful to fully understand concepts or how to do things. Record processes (walkthroughs) either capturing the screen or the activity.

Videos can be captured via Zoom, Microsoft Teams (both providing automatic transcriptions) or a video team (requires funding). All videos require preparation with the team involved as well as with other peers to clarify / identify topics and questions to include.

Effort	Strategy elements
First steps	KM 1 - Catalogue where knowledge is stored – input into accessibility tools (such as advanced search functions).
	KM 2- Create repository of PhD, MSc theses on the EUROfusion pre-print server (or pinboard) – place already exists on Pinboard, share with students and FUTTA.
	KM 3 – Organise workshop on knowledge capture and management experience, best practices and lessons learned within the EIROforum working group on Training and Career Development and share best practices with the European fusion community.
Challenging but achievable	KM4 - Support the codification of tacit knowledge to publications or video on missing priority competences supported by peer-to-peer interactions 1. Support publication of commissioning and operational experience (Beneficiaries to commit to 1 paper per fusion device per year).
Ambitious	KM5 - Support the codification of tacit knowledge to manuals or books on missing priority topics supported by peer-to-peer interactions 1. Identify and prioritise topics. Collaborate with F4E and ITER. Topics can include tokamak design work from EUROfusion devices, JT-60SA, ITER. 2. Capture know-how from retiring/retired colleagues.
	KM6 – Implement best practices on logging, creation of best practices and lessons learned to relevant Beneficiaries and EUROfusion work packages.

2.2 Building communities

The easiest way to transfer tacit knowledge is through peer-to-peer interactions. This requires identification and connection to the relevant expert(s), and a platform where the exchange can take place. Communities thus play an essential role in knowledge management.

- **Pros:** immediate value and transfer of tacit knowledge, less effort and time of the expert, provides full comprehensive support meeting current needs
- **Cons:** short term solution, not retained unless recorded, relies on the community or networking to know the right expert.

JET as a community hub

JET, the largest tokamak in the world until 2024 and holder of fusion world records, has contributed to many unique scientific and engineering discoveries. Its role as the joint European torus with over 500 European scientists visiting annually over 40 years has been equally vital in providing a place for European scientists to meet, work together and connect. Furthermore, European scientists were able to take on scientific operator roles in the JET control room, leading to exposure to a multitude of experiments and people, as well as better understanding on how to set up and analyse discharges. The community at JET has grown organically based on year(s) or decade(s) long interaction of scientists and engineers working together in teams (control room sessions or experiments) staying at JET for extended length of time (through visits and secondments). Following the closure of JET, there is currently no other place that can replicate this nurturing environment at this scale.

Medium-sized, small facilities and EUROfusion work packages

The medium size and small EUROfusion facilities provide smaller distributed scientific community hubs organised through the EUROfusion Fusion Science Department work packages. In general, operation of the facilities is however local responsibility with visiting scientists focusing on experimentation and in some cases operation of diagnostics. In general, all work packages, both in the Fusion Science and Fusion Technology Departments, provide this platform to connect and work together with peers working on similar and connecting topics.

The distributed teams and silo nature of the work packages rely often solely on the project leaders to make connections, who put dedicated effort to connect activities and people within and across different work packages. Tasks set up by EUROfusion also provide cross-functional teams across multiple work packages to ensure good communication on similar connected activities.

Formation of the JT-60SA community

JT-60SA, run under the Broader Approach Agreement with implementing agencies of QST and F4E, provides a great opportunity for European scientists to form a closer connection and community with the Japanese colleagues. Travel to Japan is expected to involve less people (around 10-15 at any point of time) and the discussion on the European participation in operation will commence after the completion of the first integrated commissioning. It will take a number of years to install enhancements, heating systems and diagnostics, and commission the systems to allow scientific exploitation of the world's next largest superconducting device.

ITER test facilities and the ITER community

Once plasma operation starts, ITER is expected to be the central hub of the international scientific community. Currently ITER is in the manufacturing and system commissioning phase with some large system components already commissioned and in operation. It is important to join the system commissioning of key plant systems to support ITER transferring the European know-how (avoid further delays), building strong collaboration with view to future operation of the systems and gaining experience to be transferred to DEMO. ITER test facilities also provide an excellent opportunity for early involvement.

EUROfusion contribution to ITER could involve sharing know-how and experience in advisory role, communities of practice and/or short/long-term tasks, visits, secondments to be negotiated jointly with Fusion for Energy and the European Commission. Furthermore, Beneficiaries take on ITER contracts and their staff can apply to temporary ITER staff positions.

Example 3 – EUROfusion involvement in the ITER Neutral Beam Test Facility
Europe is strongly involved in the future operation of the ITER NBI systems hosting the Neutral Beam Test Facility (NBTF) with SPIDER and MITICA at Conzortio RFX in Padova, Italy. Although NBTF is a bilateral agreement between Conzortio RFX and ITER, EUROfusion is involved with 13 long-term secondees and two new 2024 EUROfusion Engineering Grantees contributing to the engineering, commissioning and operation of the facilities, following the best practices of community building from JET.

Conferences and workshops
Conferences on physics and engineering provide another opportunity for experts to connect to identify collaboration opportunities.

Communities of practice in the EUROfusion Operations Network
The operational teams rarely meet or exchange their experiences and methods. Therefore, the EUROfusion Operations Networks (EON) has been set up in 2021 to facilitate the connection, sharing of experience and know-how between EUROfusion facilities. Initially, the EON network created a pilot community of practice (example 4) by organising seminars along the EON strategy shown in the table 2.

***Table 2** – Philosophy and 2-step process of the EUROfusion Operations Network (EON)*

1	**Knowledge exchange and capture, network and community building** • Increase exposure by inviting all the relevant staff (engineers, physicists, technicians, students) and organizing all events online (reduce cost and allow participation) • Accommodate busy operational schedules and future newcomers by recording all events and providing summaries. • Focus heavily on discussion and practical operational know-how, experience • Topics and structure formed by topic experts and community (bottom-up approach)
2	**Formalization of theory and practice of operations into concept of operations and training** • Identify commonalities and knowledge gaps, potential joint experiments • Develop joint understanding and identify best practices based on multi-machine experience • Refereed publications, develop concept/textbook of operations and operator training programs • **Improve and optimize machine performance and availability, develop & improve operator training**

Example 4 - NBI network of the EUROfusion Operations Network:
The first pilot community of practice was established in 2022 on the operation of positive and negative NBI systems with monthly 2-hour seminars starting in May 2022 with 35-65 experts attending each seminar. All European NBI teams joined the network including the Neutral Beam Test Facility (NBTF, Padova, Italy) and the JT-60SA team (QST, Japan) under the Broader Approach Agreement. There is close collaboration with guests including ITER and LHD (NIFS, Japan). Beyond sharing know-how and experience, initial results included offers of spare components and visits, identification of joint work on

maintenance and tools, invitation to join the commissioning of the JT-60SA NBI system in Japan and offers to share commissioning and operating procedures. F4E has joined the network in late 2023.

In 2023 the EUROfusion Operations Network and Fusion for Energy agreed to establish a joint ECRH network including ECRH teams in MPG, IPP.CR, ENEA, EPFL, KIT, UKAEA, CEA, NKUA and QST (under the Broader Approach Agreement) with ITER as guest. The joint activities will involve online and in-person meetings as well as training activities. The online seminars are expected to start in early 2024. To note, the ECRH system has been identified as a critical component at ITER for planning to maintain the schedule particularly in respect to the commissioning of the gyrotrons. With test facilities at KIT and EPFL, strong operational experience at EPFL and IPP, upcoming commissioning of new ECRH systems at CEA, QST, UKAEA and IPP-CR, Europe is well positioned to capture and transfer its expertise on ECHR operation.

Effort	Strategy elements
Continue	KM7 - Continue the EUROfusion Operations Network activities 1. Set up communities of practices on high priority operational topics (NBI in 2022, ECRH in 2024) 2. Organise workshops on priority topics driven by the need of the EUROfusion facilities (e.g. vacuum conditioning, maintenance of old equipment, JET legacy)
First steps	KM8 – Extend the number of people with oversight of the EUROfusion work package activities to enable them to act as connection points for the community Invite work package subproject leaders to relevant FSD / FTD meetings (such as the overview section of the annual strategy meeting) to get overview and identify connection points
Challenging	KM9 – Continue long term secondment scheme and set up secondment scheme to ITER (following the call for contribution at EFPW30 workshop to be involved in the preparation and commissioning activities)
	KM10 – Beneficiaries to consider involving more EUROfusion experts in scientific control room roles – WEST appointed its first non-CEA session leader in 2023. Scientific roles could involve diagnostic coordinators, real-time experts, etc.

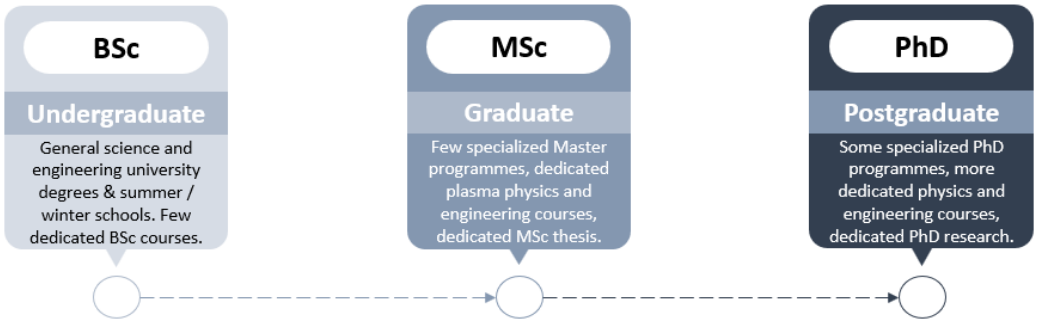
Further ideas to build stronger communities would be welcome.

2.3 Training and Education

A strong workforce requires solid foundations in academic education and follow-up training in the workplaces to ensure relevant, up-to-date skills and know-how. Increasing the presence and availability of a wide spread of fusion courses in European universities is vital to attract and retain talented students. Collective upskilling, where students are equipped with the necessary expertise/skills to seamlessly transition into the workforce, offers exceptional value for money, shortening on-the-job training times. Continuous learning offered by exposure and community engagement should be embedded in the further career development of experts.
Finally, connecting with the well-established nuclear academia and EIROforum members can provide joint training opportunities on shared topics. Such collaboration could not only facilitate the development of transferrable skills but also attract experts from interconnected fields and deepen knowledge exchange within the joint community.

2.3.1 Academic programmes and schools

The training of students starts with academic training at undergraduate (BSc), graduate (MSc) and doctoral (PhD) level followed by on-the-job training and exposure. In 2022 the EUROfusion Training and Education Office conducted a survey of the 2022 Educational Programmes to understand the availability of courses, and strengths and weaknesses of the regional education systems. The results and assessment are available in the grant deliverable reports D24.7 (2QCC2FK) and D24.1 (2PHR7S).



The Educations Programmes Overview based on self-reporting of the EUROfusion Beneficiaries and Affiliated Entities indicated that:

- Most MSc and PhD programmes include only few courses on fusion science and/or technology. There are only 2 MSc programmes and 4 PhD programmes that are fully dedicated to fusion.
- The availability of courses varies significantly geographically from none to 1-2 introductory to several courses. There are significant gaps in courses particularly in topics related to fusion engineering.
- There are no courses or summer schools on operation of fusion devices, compared to 9 physics-oriented and 2 technology-oriented summer schools.
- There is a lack of fusion engineering textbooks (2 books). There is no textbook or educational material on operations.
- Training should include more practical and interactive elements along Blooms' updated taxonomy (figure 6) in order to create deeper understanding, ability to apply and create new innovative knowledge.

***Example 5 – The Massive Open Online Course (MOOC) developed by EFPL** on plasma physics and implementation is available to the public for free and has had over 40 000 students. The course is used by universities without an introductory course and has encourage applications to fusion degrees from all over the world.*

***Example 6 – FuseNet** supports participation of students in European educational activities, provides internships internationally, supports mobility of lecturers in Europe and supports organisation of workshop or schools on scarce topics.*

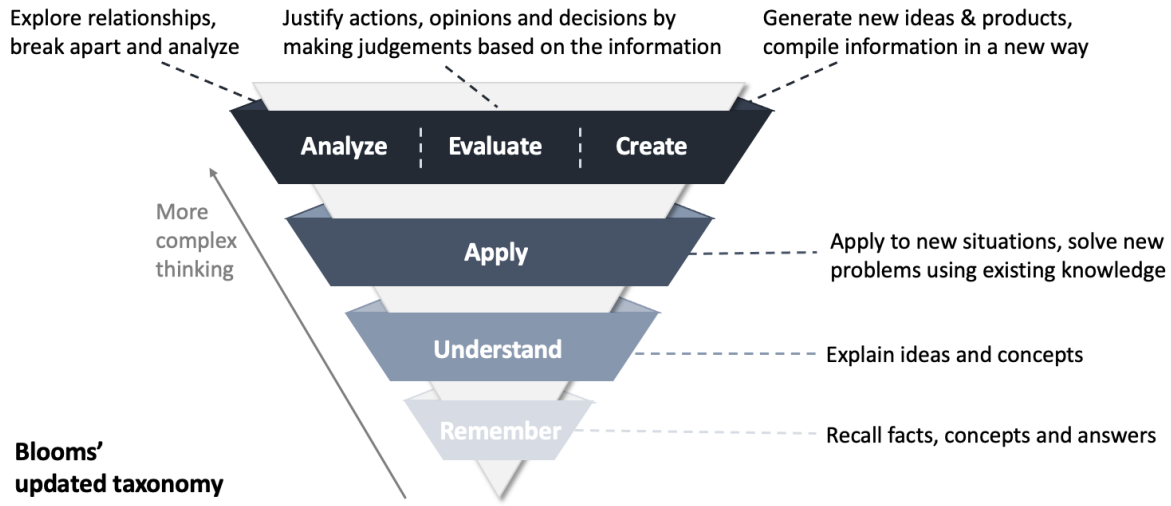


***Figure 6** – Bloom's updated taxonomy of learning from simple to complex skills*

***Use case 3:** A student listens to a lecture and asks a few questions. (S)he might or might not understand in detail and will remember elements of the lecture. Providing interactive, practical elements in the training allowing the student to apply and experiment with the concepts will lead to more complex thinking creating tacit knowledge, higher likelihood of remembering the concepts, and the potential ability to apply it to new problems and create new innovative solutions.*

***Example 7 –** The 1st edition of the JT-60SA International Fusion School (JIFS) merged topics on physics, engineering and tokamak operation based on the JT-60SA and JET experience. 2 days of practical exercises allowed students to apply what they have learned to real-life applications and problems.*

***Example 8 –** The Erasmus Mundus (EMTRAIC) Training Course provides 2-week practical research training for 2nd year master students of the Erasmus Mundus Fusion-EP Master Programme. The Summer Training Course (SUMTRAIC) provides the same training to international students. Students conduct experiments on CASTOR/GOLEM and COMPASS tokamaks followed by data analysis, theory and discussion with experts that resulted in 8 publications in refereed journals co-authored by the students.*

Effort	Strategy elements
Next steps	**KM11 - Training and Education Office to support EUROfusion funded schools and trainings** Involve the Training and Education Office in EUROfusion funded courses to support the educational side of the courses (2024: JIFS, EIROforum school, EON)
Challenging	**KM12 - Improve accessibility of available academic courses** 1. Record lectures at courses funded by EUROfusion, FuseNet and/or organised by the Beneficiaries. 2. Enable sharing of recorded courses across universities Step 1: directly with selected students with limited or no access to courses Step 2: create a EUROfusion platform (website) as repository of recorded courses 3. Create repository of practical exercises and projects
	KM13 – Increase exposure of early career scientists and engineers Provide continuous learning opportunity via internships, technical mentoring, communities of practice, invitation to join strategic meetings.
Ambitious	**KM14 - Develop new courses to fill the gaps based on a prioritized list of topics** 4. Create a publicly available introductory course on fusion engineering Step 1. School with recorded lecturers, Step 2. MOOC like example 5 5. Develop introductory course on Operations 6. Create course on engineering design of a tokamak 7. Propose priority topics for the next editions of the JT-60SA International Fusion School. Update list of topics (prioritised list of gaps) based on the annual education programmes overview and EUROfusion needs. Discuss and seek collaboration with F4E and ITER.

2.3.2 EUROfusion Grants

EUROfusion support excellent early-career scientists and engineers awarding about 10 EUROfusion Bernard Bigot Researcher Grants and 20 EUROfusion Engineering Grants every year to support their individual research and training for 2-years. The EUROfusion Engineering Training provides additional training to all grantees on various engineering topics to complement academic education building skills valuable for their career progression.

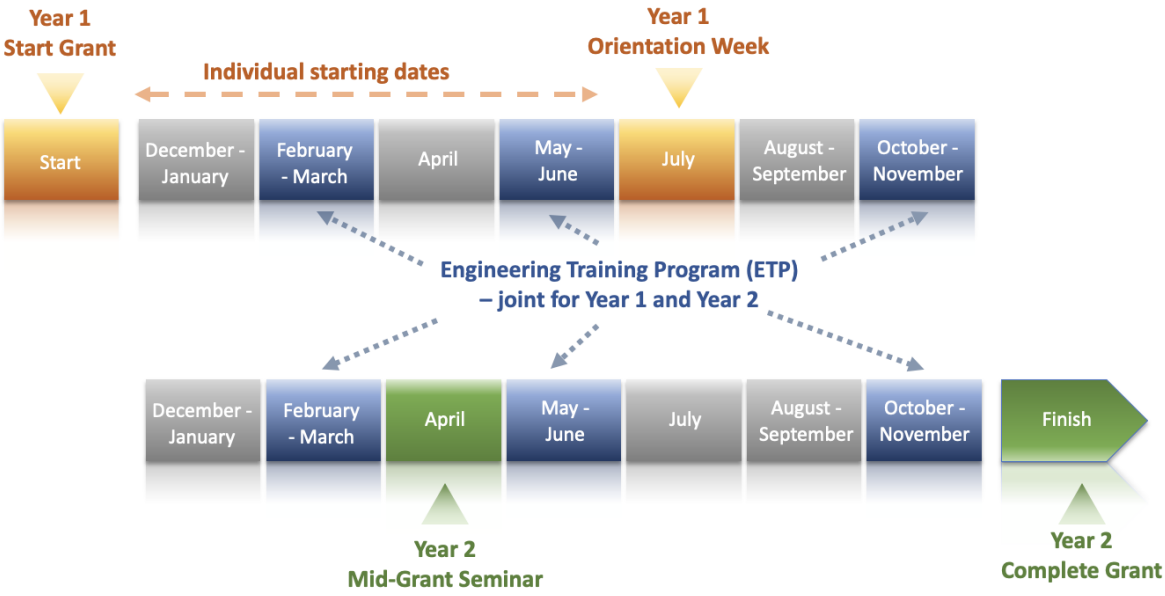


Figure 7 *– EUROfusion grant structure proposed for 2024*

Effort	Strategy elements
Next steps	KM15 - Modify the EUROfusion Engineering Training to provide more in-depth practical skill development 1. Replace monthly 4-hour sessions with six longer training sessions (2 x 0.5 days) incorporating group and individual exercises.
	KM16 - Provide opportunity for networking, feedback and community building 1. Invite new grantees for 3-days to the EUROfusion Headquarters in Garching, Germany for an induction into EUROfusion connecting with each other and the PMU experts. 2. Organise online mid-grant review seminar for the grantees to present their progress and receive feedback and support from the EUROfusion PMU, work package leaders, ERG/EEG evaluation panel members, F4E and ITER colleagues and the EUROfusion community.
	KM17 - Develop a repository of topic induction notes 1. Ask the EUROfusion Grantees to briefly describe the key resources, publications, courses and contacts that a new person entering the topic would benefit from.

2.3.3 Operator training

Operator roles heavily rely on development and use of tacit knowledge. In 2021-22 the EUROfusion Operations Network (EON) conducted a survey of the operator roles and their respective training in EUROfusion (spherical) tokamaks and stellarators. The assessment of the overview is summarized in grant deliverable D6.9 and indicated:

- The number of operator roles increases with the size of the device from small to medium-size devices. ASDEX Upgrade and JET have a similar number of operator roles (31-35 engineering roles, 11 scientific roles and 4 support roles with rostered shifts or on-call role related to the operation of the device).
- In most roles training to basic competence level takes 2-6 months and 1-3 years to become an expert operator. The exception with training over 1-year are tritium operators (3 levels with 1-3 year each) and session leaders (physics pilot, 3 levels with > 1 year each) on JET.
- Experience from other devices can reduce training time up to 50%.
- Training is often on the job starting by shadowing other operators. In selected roles, lectures are provided and in some cases there are written commissioning and operating procedures.

The **session leader** (physics operator) role is particularly interesting. It encompasses understanding (and development) of plasma scenarios, engineering and physics limits of plasmas and the plant systems, how to programme a plasma discharge to achieve the physics target while exploiting the plasma and engineering space to the maximum in a safe way and management of the control room. Furthermore, the know-how supports the optimal development of experimental proposals pre-session and analysis of discharges post-session, thus would be beneficial to students, scientific coordinators, task force leaders and any scientists contributing to experiments. Finally, a basic understanding of the role can also provide newcomers to fusion with a basic understanding to tokamak operations. In 2024 the development of an introductory course on session leading and operation is foreseen under the EUROfusion Operations Network.

Effort	Strategy elements
Challenging	KM14 topic priority - Develop introductory course and educational material on Operations 1. Develop the Foundation Courses on Session Leading and Operation planned in 2024 – aligned with strategy KM14 Step 1: create lecture slides and organise course Step 2: create written material for the course, Step 3: write textbook

2.4 Accessibility and tools

EUROfusion stores information on a variety of platforms, IDM, SharePoint, Indico, wiki pages and the Users website. It is important to understand which information is stored where and **have a clear starting point** where information can be found and who the contact people are. Secondly, knowledge stored is only useful if **experts are aware that it exists and it is easily accessed**.

ID	Strategy
First steps	KM18 - Have a clear starting point on the EUROfusion wiki pages on where information is stored for each of the EUROfusion work packages and indicate the main contact people for various topics and competences.
Challenging	KM19 – Catalogue and curate what knowledge is stored and available 1. Catalogue the EFDA library in the basement of the EUROfusion Headquarters.
Ambitious	KM20 – Develop a centralized advanced search function connected to pinboard, IDM, SharePoint, wiki pages and/or knowledge basis. Extend potentially to individual databases such as emails and personal notes accessible only to the individual.
	KM21 - Embed the knowledge base into everyday processes 1. Test on small scale for example by development of AI tools to support operators (2024 WPPrIO task)

2.5 Combination of activities

The four elements of the EUROfusion Knowledge Management Model support and strengthen each other when combined.
Examples:

- Combine **codifying knowledge** (writing it down) with seminars allowing **peer-to-peer interactions** (identify concepts unclear, key questions / know-how / experience to include in the written document) and **training**.
- **Capture in video format tacit knowledge transfer in action,** i.e. peer-to-peer interactions within **communities of practice**. Provide transcriptions, then summaries that can support the final codification of the key know-how and experience.
- **Create a training first** (e.g. 1-week course with presentations) to test and optimize concepts, best practices, sequence and way of how concepts are introduced **before codifying it into manuals and textbooks**.
    - Create lectures with presentations. Test and optimize it. Record video with automatic transcription.
    - Write education material to the course.
    - Write manual and/or textbook.

  This stepwise process provides optimization, quick wins with immediate value to the community, while progressing to the final goal of a manual or textbook or concept document.

III. External stakeholders

Sharing knowledge with external partners relies on the availability of an appropriate framework governing intellectual property.

It is important to identify and seek out collaboration opportunities with external partners based on the needs of the EUROfusion Beneficiaries and Affiliated Entities. Collaboration with international publicly funded laboratories shall continue along the established connection points. Collaborate with F4E to increase the knowledge management activities under the Broader Approach Agreement.

Following the feedback on the EUROfusion Knowledge Management Strategy by the EUROfusion Beneficiaries, seek out collaboration opportunities with F4E and ITER, and support from the European Commission through the creation of a dedicated working group.

Collaboration with private companies and industry will be discussed and managed under the dedicated EUROfusion Programme Management Unit activities and are not included in this strategy.

EUROfusion has established interaction and collaboration with industry through the Fusion Technology Transfer (FUTTA) programme. A particular effort is to be devoted to the increase of awareness on Intellectual Property Rights among scientists and to implement processes to systematically review the Intellectual Property Right content of industrial contracts and of all new projects in their early stage of development. The Technology Transfer programme supports scientists in understanding the strategic values of the outcome of their research activity, and in identifying the most suitable form of Intellectual Property Right protection. A Knowledge and Intellectual Property management system is implemented to guarantee the maximum exploitation of knowledge generated in fusion research, and result in a significant socio-economic impact.

Effort	Strategy elements
First steps	KM22 - Set up working group and/or contact points at F4E and ITER to collaborate and coordinate the joint Knowledge Management Activities.
Challenging	KM23 – Raise awareness of the fusion technology transfer opportunities of technologies that can be used in industrial applications outside fusion.
	KM24 – Inform scientists about intellectual property protection
Ambitious	KM25– Where not available, set up the necessary agreements to govern intellectual property.

IV. Implementation

The EUROfusion Knowledge Management Implementation Plan will be prepared following the discussion and feedback on the EUROfusion Knowledge Management Strategy submitted to the General Assembly meeting in December 2023. The staged-process was chosen to ensure the support of the EUROfusion Beneficiaries required to successfully carry out new knowledge management activities.
When committing to knowledge management activities with manpower and budget, it will be important to review the human interaction and/or effort required, the level and timing of transfer of explicit and tacit knowledge similar to figure 8.

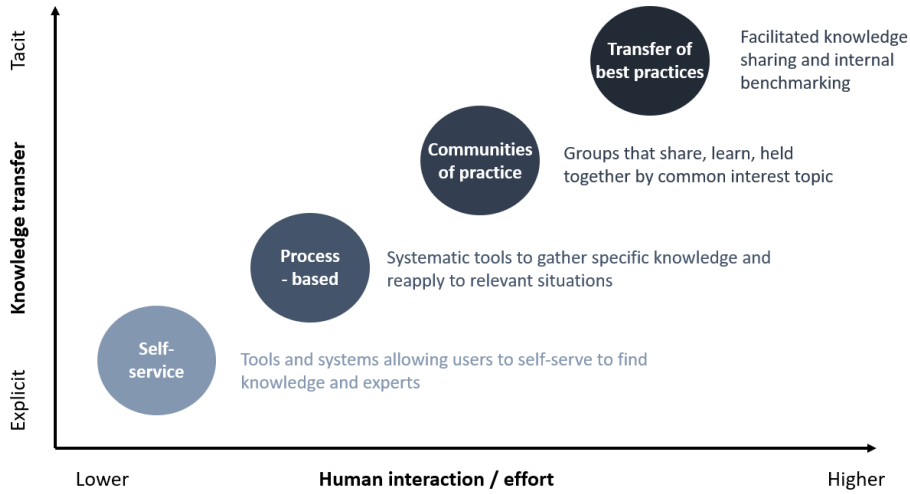


Figure 8 – Expected human interaction and effort requirements of common knowledge management activities.

The implementation plan will focus on the initial steps in 2024-25 with the goal to build a culture that fosters knowledge capture, sharing, collaboration embedded in everyday processes and interaction. Knowledge management relies heavily on support of all stakeholders from senior to junior levels, thus the plan will use key elements of Kotter's 8-step change model, while identifying risks and mitigating actions.

Figure 9 – Kotter's 8-step change model focusing on communication, support of stakeholders, visible quick wins and development of a nurturing flourishing culture.