https://doi.org/10.20965/ijat.2018.p0553

Paper:

Consideration of Tacit Knowledge Sharing by Automation for Reinforcement of Human Abilities: Empirical Comparison of Conservation Techniques Between Japan and Denmark

Sadayo Hirata[*,†] **and Mika Yasuoka**[**]

[*]Graduate School of Engineering Management, Shibaura Institute of Technology
3-9-14 Shibaura, Minato-ku, Tokyo 108-5848, Japan
[†]Corresponding author, E-mail: hirata-s@shibaura-it.ac.jp
[**]DTU Management Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark
[Received December 22, 2017; accepted May 14, 2018]

It is vital for cultural properties to be passed down between generations. Therefore, this study focuses on conservation techniques and discusses a system that provides appropriate automation to prevent the destruction of the value of cultural properties and conservation techniques. Manufacturing companies have improved productivity by rapidly replacing humans with machines. Because of this, the techniques of skilled persons who have gained experience with products over time by maintaining and repairing them are not being inherited by their successors. This has resulted in many manufacturers ceasing production or going out of business. Cultural properties are strongly associated with tradition and tacit knowledge. This makes it more difficult to maintain and reproduce them than common products. Thus, rather than a simple replacement of people and machines, support through applying automation that enhances human abilities is required. This study investigates Japan and a developed country, Denmark, in terms of conservation. On the basis of mutual understanding gained by investigating the state of mutual conservation in the two countries, we summarize the problems and efforts related to tacit knowledge sharing. We used a qualitative research method called ethnographical inquiry to find tacit knowledge underlying the techniques and influences of culture in Japan and Denmark. This study features empirical findings on the appropriate use of both automation that replaces humans with machines and automation that enhances human abilities.

Keywords: conservation, ethnographical inquiry, intelligent system, management of technology, tacit knowledge

1. Introduction

Automation became common thanks to the Industrial Revolution. It brought us shorter hours, standardization, and reductions in cost, thereby making mass production possible. It freed humans from long hours of labor and dangerous work. Such automation has become popular in large companies, as it allows them to replace humans with machines. The definition of automation changes with the times and is recognized now as machines and machine groups working automatically.

However, the number of people with maintenance and repair skills, who must have detailed knowledge of developments over time and complicated combinations of conditions, has been reduced, causing companies to cease production or go out of business altogether. In addition, scarcity value is adversely appreciated now because mass production supplies too many products.

To solve these problems and to obtain more benefits from automation, the definition of automation should be expanded from "machines and machine groups" to "a collaboration between human and machine."

Therefore, we define two viewpoints of automation as "substitution of machines and human beings" and "reinforcement of the human ability that it is difficult to be replaced by machine," as presented in **Table 1**.

The conservation of cultural properties is one domain that should hasten the reinforcement of human abilities. Moreover, cultural properties are strongly associated with tradition and tacit knowledge, so they are more difficult to maintain and reproduce than common products. Passing cultural properties down through generations, unlike simple repairs, requires appropriate conservation based on an understanding of long-term changes in manufacturing and the environment, from the time they were manufactured up to the present [1–3].

However, there is a problem: like those skilled in maintenance and repair, some techniques of cultural properties, which were scattered in the form of tacit knowledge possessed by individual craftsmen, have already been lost

Table 1. Two viewpoints of automation in this study.

No.	Roles	Expected Effects	Targets
1	Substitution of machines for human beings	Reduction of cost, Shortening of hours, Standardization	Mass production
2	Reinforcement of the human ability that it is hard to be replaced by a machine	Tacit knowledge sharing, Diversification, Differentiation	Limited production of a wide variety of products

owing to the replacement of humans with machines [1–3]. To solve this problem, there is an urgent need to support rare craftsmen who possess the techniques of cultural properties.

With the goal of passing precious cultural properties down through generations in mind, this study intends to find a system to pass on manufacturing and conservation techniques, taking advantage of automation that enhances human abilities. More specifically, this study intends to visualize the tacit knowledge of the traditional techniques and provide support in passing it on to successors without spoiling its values.

To achieve this goal, this study first defines a framework of conservation technique inheritance. Next, based on this framework, we discuss the problems and efforts related to the tacit knowledge of conservation techniques. Then, we build a system that appropriately uses both viewpoints about automation defined in **Table 1**, and evaluate the effects. Finally, using a comparison between Japan and an advanced country (Denmark [3]) in terms of conservation, we conclude with our results and a discussion of the inheritance of traditional techniques.

This study is characterized by the following two features. One is that the roles of automation are split into two types, as presented in **Table 1**, and thus the share of conservation techniques is complemented and supported by automation that enhances human abilities but is also being lost owing to automation that replaces humans with machines. The other is the use of ethnographical inquiry [4–6], which is a research approach appropriate for understanding intangible and latent information. In this way, tradition, culture, and other qualitative data are handled.

In this study, "cultural properties" refers to buildings and industrial products. This study does not target paintings and other types of artwork or their philosophical ideas.

2. Issues

There are three main stakeholders involved in the inheritance of conservation techniques: craftsmen, who are in charge of restoration; clients, who order the restoration; and the country or society that maintains its tradition through cultural properties. The three stakeholders have the following issues.

2.1. Information Scattered Across Craftsmen

The manufacturing process and components of cultural properties are broken down into a wide range of elements, all of which are highly specialized. For this reason, manufacturing technology exists in a scattered, latent manner as the tacit knowledge of the craftsman who is in charge of each step, and hence a complete picture is difficult to obtain [7].

2.2. Ordering Parties Tend to Prioritize Economic Efficiency

Behind the gradually disappearing traditional techniques of cultural properties, ordering parties tend to give priority to economic efficiency and make do with easy repairs rather than conservation [8].

When it comes to conservation, there are two restoration policies to choose from: reproduction of cultural properties as they were manufactured, and preservation of the status quo over time [1–3]. Deciding between the two requires data on changes in the climate and environment from the days the properties were manufactured up to the present, the compatibility between the materials used in those days and modern chemicals, and so on. However, because conservation does not occur frequently, or even if conservation does not occur at all, it does not cause any risk to life or immediate inconvenience. The importance of records for conservation tends to be underestimated [8].

2.3. Unrecognized Conservation Techniques

There are many countries that do not grant conservators an official certification, and thus the craftsmen in charge of conservation have low social status in general [3].

The earliest definition of the duty of conservation was made in 1963 by the International Institute for Conservation of Historic and Artistic Works (AIC) in the USA. Following that, in 1985 the Canadian Association for Conservation of Cultural Property (CAC) and the Canadian Association of Professional Conservators (CAPC) established practical guidelines [8]. The main work regulations are presented in **Table 2**, based on investigations into work regulations for conservators in North America, Europe, and Japan [3, 8].

In Europe, where conservation developed earlier than in North America, Denmark adopted work regulations in 1964 for conservators in cooperation with the International Council of Museums-Committee for Conservation (ICOM-CC). As a complement, the European Confederation of Conservators-Restorers' Organisations (ECCO) released guidelines in 1991 [3]. When put together, these regulations and guidelines cover the standards more thoroughly than those of North America.

Japan has an institute that promotes the Western countries' standards [3], but does not yet have work regulations or an official certification.

Table 2. Conservation technique inheritance based on work regulations.

Labels	*Framework of Conservation Technique Inheritance*	*Reference of Work Regulations*			
		North America		*Europe*	
		AIC	*CAC&CAPC*	*ICOM-CC*	*ECCO*
A	Respect for restoration target and the like	Y	Y	Y	Y
B	Respect for values such as truthfulness and completeness		Y	Y	Y
C	Emphasis on preventive maintenance	Y	Y		Y
D	Practice of high quality work	Y	Y		Y
E	Use of appropriate materials and methods	Y			Y
F	Creation and disclosure of investigation records	Y			Y
G	Importance of cooperative work			Y	
H	Need for scientific investigation			Y	

Note Y: Regulation is descripted.
AIC: International Institute for Conservation of Historic and Artistic Works
CAC: Canadian Association for Conservation of Cultural Property
CAPC: Canadian Association of Professional Conservators
ICOM-CC: International Council of Museums-Committee for Conservation
ECCO: European Confederation of Conservators-Restorers' Organisations

Work regulations are established in order to specify roles and duties. At the same time, work regulations express the ability to require tacit knowledge. Therefore, without work regulations, it is difficult to develop, evaluate, and share the abilities.

3. Research Methods

As presented in **Fig. 1**, a conclusion was drawn based on a comparison of case studies carried out in Japan and Denmark.

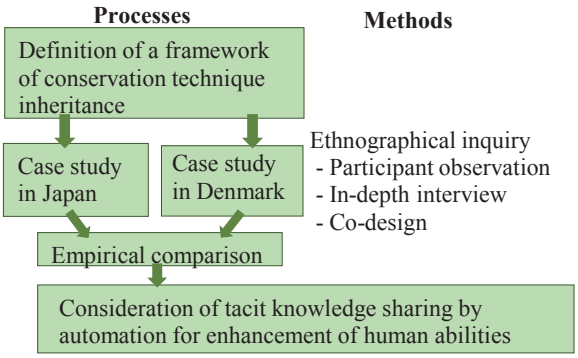

Fig. 1. Research processes and methods.

3.1. Framework of Conservation Technique Inheritance

In this study, a framework of conservation technique inheritance was defined as the eight points shown from A to H in **Table 2**, quoting the work regulations of the conservation. This framework was used to compare Japan with Denmark based on common viewpoints.

As presented in **Fig. 1**, we carried out discussions based on a case study in Japan, a field survey in Denmark, and a comparison of data from both of those countries.

3.2. Ethnographical Inquiry

To understand craftsmen's tacit knowledge and related practices, we utilized a few ethnographical inquiry approaches. An ethnographical inquiry can help us to "understand other people's behavior in the context in which it occurs and from the point of view of the people studied" [4, 9].

A wide range of ethnographical methods has been used in various applied fields such as service [10, 11], product organization [7], and human resource development [12]. Previous studies indicate that these methods are applicable to the automation technology domain as well as to anthropology and sociology, as they preserve core values such as the natives' points of view, holism, and the natural settings of the targeted actions. Ultimately, ethnographical inquiry, which is different from the ethnography in anthropology, should aim at changing the design field through understanding that "what we design is not just artifacts but by intervention a changed or reformed practice" [13].

Seeing ethnographical inquiry from such a design perspective, our case also aims to change practices through design interventions.

i. Participant Observation

In ethnographical inquiry, participant observation is one of the most distinctive investigation methods. Partici-

pant observation makes it possible to visualize and externalize the tacit knowledge of an observer who participates in ongoing activities and records observations.

In our case, the observers participated in craftsmanship practices throughout the observation periods. We will elaborate on our participation in more detail in Sections 4.3 and 4.4.

ii. In-Depth Interview

In-depth interviews are also a prominent method for understanding practices in the field. The core concept behind in-depth interviews is clearly visible in contrast to the conventional scientific approach to interviews. Traditionally, interviews have been utilized to depict facts that already exist somewhere. However, in in-depth interviews, opinions are constructed through interactions between the interviewee and interviewer. Thus, in-depth interviews are called "conversation(s) with purpose" [5] and are a form of co-creation with interviewees. Our in-depth interviews also applied this conversation perspective.

iii. Co-Design

Co-design is an established design approach used to design things, services, and processes. It attempts to actively involve stakeholders in the design process to ensure the equality and empowerment of end users [6], usability, creativity, and innovation [14, 15]. It has its roots in the participatory design practiced in Scandinavia since the 1970s [16] and practiced in North America since the 1980s [17]. Co-design deals with a challenge by involving end users in the design processes of information systems [18] and varied methods such as the design of games [13, 19, 20], the Kawakita Jiro method [21], brainstorming [22], and theater and scenarios [23, 24].

In our study, we conducted co-design with Japanese craftsmen in designing a preliminary automation system for inheriting conservation techniques. We applied co-design methods to explore the possibilities for a practical support system for craftsmanship and to have meaningful interactions with and design improvements with and for craftsmen as end users. Details will be provided in Section 5.

In our analysis of the collected data, we applied grounded theory [25, 26]. Grounded theory is a qualitative analysis method used to describe the mechanism of a social phenomenon. The actual research procedure of grounded theory includes creating a document for recording participant observations, interviews, and the like; breaking up the document into fragments and coding them with numbers or labels; deriving a causal relationship between codes and a structure; and presenting a new hypothesis or theory on the basis of the causal relationship and structure. Grounded theory is different from other qualitative analysis methods in that it presents factual data as a base and provides an objective analysis.

3.3. Case Study in Japan

This case study targeted a small company (Company A) in Japan that has approximately 20 employees and is a contract manufacturer of components for buildings. It specializes in casting, which is where molten metal is poured into a sand mold. Casting makes possible sophisticated curves and textures that could never be realized through metallic molding and cutting. Taking advantage of this traditional technique, Company A also restores cultural properties.

Table 3. Data collection in Japan.

Methods	*Informants*	*Ethnographers*	*Total Time (hours)*	*Places and Profiles*
Participatory observation and field observation	15	6	9	Foundry, Office, Rest room, Warehouse
In-depth interview	6		9	Management, Chief, Craftsmen

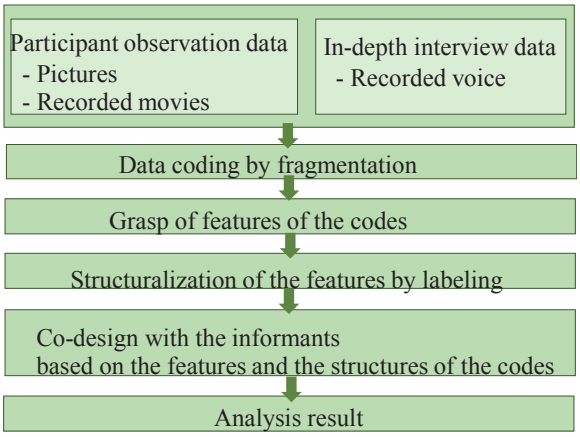

Fig. 2. Analysis processes in case study in Japan.

As shown in **Table 3**, this case study was carried out at Company A. We collected factual data from June to December 2015 through participatory observation, a field observation, and an in-depth interview. An investigation of the actual condition was conducted by six ethnographers, including students from a class on ethnographical inquiry. A total of approximately 18 h of movies and audio and approximately 600 photos were collected.

We then transcribed the recorded voices, photographs, and videos and coded them in sentence units [7] according to the analysis processes shown in **Fig. 2**. At first, we extracted characteristic tacit knowledge of the conservation from all codes about behavior and recognition of the craftsmen engaged in the conservation to understand the actual situation. We then used eight types of tacit knowledge from A to H, defined as a framework of conservation technique inheritance in **Table 2**, and attached the labels for some codes that expressed the above-mentioned characteristic. We structured the tacit knowledge that was un-

Table 4. Data collection in Denmark.

Methods	*Informants*	*Ethnographers*	*Total Time (hours)*	*Places and Profiles*
Participatory observation and field observation	6		9	Conservation sites, factory
In-depth interview	33		16.5	Craft experts, Teacher

derlying in Company A in this way.

Referring to these results, a co-design was carried out together with craftsmen, information and communication technology (ICT) engineers, and students. We repeated suggestions for an iterative concept, then discussed, refined, and finally proposed a Tacit Knowledge Sharing System that could provide the automation to reinforce the ability of the craftsmen having superior traditional techniques [7].

3.4. Case Study in Denmark

To understand the actual conditions of the inheritance of conservation techniques in Denmark, we collected data in July and September 2017, as presented in **Table 4**.

First, we visited a school of conservator education for approximately 3 h. Next, in a castle where the interior was under restoration, a house, and a restoration studio, we observed the work of six conservators using a participatory observation method for a total of 6 h.

In addition, we carried out participatory observations and interviews targeting 33 persons: front-line conservators who had graduated from a conservator school and were working for a public or private institute or working independently, teachers, and craftsmen who were experts in craft work. We recorded as much audio and video as possible, and had 30-min interviews with each person. The recorded voices were transcribed and coded as in the Japanese case study.

4. Results

4.1. Results of Case Study in Japan

4.1.1. Grasp of Features of Codes

The four characteristics in behavior and recognition of the craftsmen engaged in conservation were extracted according to the analysis processes of **Fig. 2** as follows. Furthermore, an applicable label among H from A of the framework of conservation technique inheritance is indicated in a bracket at the end of a sentence, when the code expressing the characteristic is related to the tacit knowledge.

i. Abilities Difficult to Explain with Words

Overall, contract manufacturing is my main job. Thus, there are few jobs where I utilize my specialty technique. The restoration of cultural properties is very challenging (A); I worked on it without any thought of profit (A). For example, I repeated the procedure many times with varying blends of metal until the dark shining color became the true color (B).

I add some elaborations, such as the prevention of abrasion to the design, even if not required at the time of the order (C). However, as I do not have any direct contact with the end user, I cannot explain or confirm its effect (C).

I am confident in my technique, but it is difficult to verbally express this (H). If my technique remains as a cultural property, it will work as a substitute explanation for families or clients, and I am proud of it as well (A).

ii. Partial Scattering in Each Craftsman

The casting process includes phases such as mold creation, casting, and polishing, each of which is done by a specialized craftsman. Small-scale factories cannot afford to employ a specialized craftsman for each phase (E). They finish their work with mutual help from neighboring small factories (E). There were some craftsmen employed from other factories with decreasing orders (G).

iii. Cover-Up for Isolation and Respect

A polishing craftsman created fine curves even at his own expense by producing jigs (D). However, he did not want to teach his know-how to others because he did not want them to take his own work (F). The craftsmen had a habit of drawing the line at disclosing their know-how, and refrained from invading others' territory out of respect for each other, even though they offered cooperation (G).

iv. Divided Work Style

A closed work style based on isolation and respect was often seen not only in conservation but also in daily work. They shared hand-over items at the morning and evening meetings (E), but the storage locations of the molds and tools, the progress of the work, and so on were only known to the persons in charge (G). The work was interrupted many times to search for molds and tools, check for allocation and progress, and the like (D).

4.1.2. Structuralization of Features by Labeling

The results that structured the tacit knowledge by labeling are listed in **Table 5**. According to **Table 5**, it was found that both tacit knowledge and tacit knowledge inhibition were in Company A. In addition, Company A was good at D: practice of high-quality work and E: use of appropriate materials and methods. On the other hand, it was lacking in F: creation and disclosure of investigation records and H: need for scientific investigation.

Accordingly, we determined that the items that most required improvement were label F in **Table 5**, "I do not want to decrease my own work because I have to teach

Table 5. Codes related to tacit knowledge extracted from case study in Japan.

Labels	*Framework of Conservation Technique Inheritance*	*Codes on Tacit Knowledge to be Shared*	*Codes on Behaviors to Block the Tacit Knowledge Sharing*
A	Respect for restoration target and the like.	Have a strong feeling of challenge for restoration work.	—
B	Respect for values such as truthfulness and completeness.	Repeat many times until it becomes close to the real thing.	—
C	Emphasis on preventive maintenance.	Design a mechanism that prevents abrasion, added even if not requested.	Impossible to directly confirm the effect of prevention.
D	Practice of high quality work.	Stick to the outcome even by creating jigs of their own expense.	Frequently interrupt the work.
E	Use of appropriate materials and methods.	Mutually help neighboring small factories. Share hand-over items in meetings.	Can not afford to employ person in charge of each process of casting. Where to store the molds and tools, progress of the work, and the like were only known to each person in charge.
F	Creation and disclosure of investigation record.	—	"I do not want to decrease my own work because I teach know-how to others."
G	Importance of cooperative work.	Employ craftsmen from factories with decreasing orders.	Have a custom of refrain from invading each other's territory.
H	Need for scientific investigation.	—	"I am confident in my technique, but it is difficult to verbally express."

know-how to others," and label H, "I am confident in my technique, but it is difficult to verbally express this." Hence, we discussed a method to support the improvement of these two items.

4.1.3. Co-Design with Informants

Based on the characteristics and structures analyzed by the codes described in Sections 4.1.1 and 4.1.2, co-design was carried out with the informants. As a result, in order to support sharing and explaining traditional techniques, we planned to create a system to support the sharing of individual tacit knowledge through automation to reinforce the human ability that it is difficult to be replaced by a machine.

i. Extraction of Specific Tacit Knowledge

We extracted 13 behaviors of tacit knowledge to be shared among the manufacturing and conservation techniques from the codes describing the work of the craftsmen. The results are listed in **Table 6**.

The process of casting is divided into phases that are each handled by a specialized craftsman. Thus, it is difficult for an individual craftsman to understand what advantages are brought to the other phases. For this reason, we read codes on the work of all craftsmen, gathered the tacit knowledge for each work, and sorted them.

ii. Sharing Methods of Tacit Knowledge

Next, appropriate sharing methods for each item of tacit knowledge were classified into the following three types (see **Table 6**): optimal for sharing (best), appropriate (good), and inappropriate (NG or no good). We confirmed that formalization and replacement were possible even for know-how for which there were comments such as, "I do not want to teach" and "It is difficult to verbally express this."

However, even if there is the possibility of substitution by automation to replace humans with machines, some forms are not appropriate for the small-lot production of various products, such as conservation from the point of view of work efficiency and cost effectiveness [27–30]. Their feasibility is discussed in detail in other studies, and hence is omitted from this study.

iii. System that Visualizes Tacit Knowledge and Sharing Methods

Among the sharing methods listed in **Table 6**, we targeted the tacit knowledge for which any documents, photos, or videos were determined as "Best" or "Good." With the craftsmen, we discussed the sharing of their abilities that are difficult to be replaced by machine via automation.

Based on this, we designed a Tacit Knowledge Sharing System to support the inheritance of valuable human abilities. More specifically, based on codes through participant observation and in-depth interviews with the craftsmen, we discussed, understood and registered tacit knowledge to be shared into a database of the Tacit Knowledge Sharing System. Molds and tools related to the registered data were tagged with radio frequency identification (RFID) tags. Thus, reading an RFID tag with a reader allowed techniques to be extracted from the database using appropriate methods.

Table 6. Comparison of sharing methods of tacit knowledge inheritance.

Tacit Knowledge to be Shared	*Choice of Tacit Knowledge Sharing Method by Co-Design*				
	Possibility of Application of Automation to Replace Humans with Machines	***Documents***	***Photo***	***Video***	***OJT***
(1) Capable of determining the dimensions of patterns and anticipating shrinkage allowance and warpage of finished model.	- Computer-aided design (CAD) / Computer-aided manufacturing (CAM) [27] - Three-dimensional (3D) data [27] - Sensor [28] - Vibration controller [29] - Power assist [29] - Traceability through business model management [30]	NG	NG	NG	Best
(2) Capable of increasing the purity of metal to be casted by adding a groove and inflection to the mold for precipitation and flotation of impurities.		Best	Good	NG	Good
(3) Capable of adding a projection that enables product to be taken out without breaking the mold upon dismantling.		Good	Best	NG	Good
(4) Capable of adjusting the model after a defect is found.		Good	NG	NG	Best
(5) Capable of tactually judging moisture of sand mold to prevent air bubbles in casting (7% to 10%).		Best	NG	NG	Good
(6) Capable of uniformly producing multiple sand molds.		NG	NG	NG	Best
(7) Capable of estimating the amount of impurities generated based on blending ratio of materials.		Best	NG	NG	Good
(8) Capable of pouring in a way that controls air bubbles.		NG	NG	Good	Best
(9) Capable of skimming off foam by the appropriate number of times.		NG	NG	Good	Good
(10) Capable of breaking the mold without breaking the contents by the appropriate strength and direction of force.		NG	NG	NG	Good
(11) Capable of choosing easy-to-cut tools in accordance with the characteristics of the metal.		Best	NG	NG	Good
(12) Capable of creating jigs for creating curves that machines cannot do through cutting and polishing.		NG	Good	NG	NG
(13) Capable of controlling quality standards for each client.		Best	NG	NG	Good

Legends for judgment standard: Best: optimal as an option, Good: can be an option, NG: inappropriate for an option

This system can provide automation functions of collection and preservation of information such as tacit knowledge. Furthermore, it can provide roles to inherit tacit knowledge by understanding the information through the system. In other words, the Tacit Knowledge Sharing System utilized the two viewpoints of automation presented in **Table 1**.

iv. Evaluation and New Issues

We observed the craftsmen as they used the Tacit Knowledge Sharing System.

The videos drew their attention first. A new understanding and realization was promoted by videos of techniques that included a significant amount of tacit knowledge. The craftsmen were strongly interested in videos of themselves. It was an opportunity for them to see themselves objectively. They naturally requested more photos and videos, and wanted to record the entire process and use it for self-study, see everyone's techniques, and so on.

In addition, a technical limit was that the RFID reader did not respond if metal was nearby; moreover, the RFID tags hindered manual work.

This experiment indicated the following:

- Once broken up, even techniques involving much tacit knowledge can be explained and shared via documents, photos, videos, and on the job training (OJT).
- Even for tacit knowledge that tends to be hidden owing to isolation and respect, resistance against sharing it was reduced, stimulated by automation that enhanced human abilities.
- Unlike the investigation results of existing white papers, which uniformly point out the low literacy related to automation, automation that enhances human abilities can be accepted by craftsmen.

4.2. Results of Case Study in Denmark

4.2.1. Data by In-Depth Interview

In Denmark, most conservation work from the 19th to early 20th centuries was carried out in workshops at major museums, and training was conducted as a part of apprentice-master relations in each individual workshop [1, 2]. The Ministry of Culture in Denmark established the School of Conservation in 1973. The school has since become a part of the Royal Danish Academy of Fine Arts, and takes 40 undergraduates students every third year in five departments. In addition, the school provides Master's and Ph.D. programs and promotes academic research on conservation [1, 2].

Table 7. Codes related to valuable abilities extracted from case study in Denmark.

Labels	*Framework of Conservation Technique Inheritance*	*Codes on Tacit Knowledge to be Shared*
A	Respect for restoration target and the like	Have strong pride and a feeling of challenge for conservation techniques.
B	Respect for values such as truthfulness and completeness	Make judgment by using both knowledge and sense.
C	Emphasis on preventive maintenance	Consider difficulty in abrasion and the like even if not required.
D	Practice of high quality work	Can receive five-year professional education.
E	Use of appropriate materials and methods	Choose from abundant materials and methods that have been acquired.
F	Creation and disclosure of investigation record	Writing papers is encouraged. Disclosed by universities and others.
G	Importance of cooperative work	Mutually understand professional territory and work on it as a team.
H	Need for scientific investigation	Acquire also an ability of logically and scientifically communicating with the client.

At present, the Danish government is fostering an optimal number of persons in necessary fields, one of which is conservation. Most of the fostered conservators belong to municipalities and are engaged in the restoration of cultural properties that are owned by the national government or local municipalities, belong to the private sectors, or have become independent and have undertaken conservation.

Conservator fostering education is made up of both the systematic study of necessary knowledge for conservation and hands-on learning of tacit knowledge. In addition, academic research has been emphasized in recent years. Conservators often restore conservation techniques on the basis of past materials and scientific analyses [1].

4.2.2. Grasp of Features of Codes

The four characteristics in the behavior and recognition of the conservators were extracted according to the analysis processes of **Fig. 2** as follows. Furthermore, an applicable label among H from A of the framework of conservation technique inheritance is indicated in a bracket of the end of a sentence, when the code expressing the characteristic is related to the tacit knowledge.

i. Basis and Confidence Backed by Higher Education

The Royal Danish Academy fosters conservators. Students choose one of five specialized fields and spend five years mastering it. The students develop not just expertise but also a logical, scientific ability to verbally communicate with their clients (D, H). Discussions among them indicated their pride and confidence, backed up by the five years of education.

At a restoration site, they undertook a careful investigation and chose the optimal restoration method and materials (E). On the other hand, there were many cases of sensory judgment (B). For example, "The glue that was always used and still remains slightly on the wall is a little greasy and has a unique, animal-like smell. So, I guess it is not varnish but shellac [both are used for gloss and waterproofing]" (H).

ii. Emphasis on Expertise and Cooperation

A team is formed for large-scale restorations such as the interiors of castles and houses. We observed the restoration of a private residence that was handled by four people. There was a good cycle where the more the craftsman deepened his practice and expertise, the more likely he was to be invited to a new team (G).

iii. Contributions of Individuals to the Group

Conservation techniques were made open by the Royal Danish Academy in 1973 (F). Now, the writing of papers on newly found knowledge is encouraged. In addition, they are also proactive about acquiring overseas technologies through workshops and academic societies (H).

iv. Self-Independence and Coexistence

Even though the students graduate from a school for conservators, a stable job is not guaranteed. However, most of the conservators we interviewed mentioned the importance of deepening their expertise after graduation (A).

For self-independence, sociality is also important. It is difficult for conservators who have just graduated to find a job. They use personal connections with conservators to find jobs.

4.2.3. Structuralization of Features by Labeling

The results that described the characteristics in Section 4.2.2 and structured the tacit knowledge by labeling are listed in **Table 7**. According to **Table 7**, it was confirmed that the eight items of tacit knowledge were shared through behavior and recognition of the conservators without being inhibited.

5. Discussion

Based on the comparison of case studies in Japan and Denmark described in Section 4, we will explain four main aspects of the differences in the inheritance of conservation techniques in both countries.

5.1. Making Tacit Knowledge Open

In Japan, conservation is carried out in addition to one's regular job. The conservators have confidence in conservation, but also have a relatively closed tendency within their personal tacit knowledge. On the other hand, conservators in Denmark carry on their conservation work even though it is unstable and they must keep expanding their expertise. They have an open tendency toward coexistence through recording and disclosing their techniques. This is an outcome of familiarization with automation that gradually enhances conservation techniques for craftsmen, as presented in **Fig. 2**, which was part of the efforts made by the Royal Danish Academy and others.

5.2. Thoughts and Cooperation to Maintain Tacit Knowledge

In Japan, the Tokyo University of Arts provides education in the techniques and history of Japanese-style paintings and other traditional arts, and Hakataori Development College provides practical education in traditional techniques.

In Denmark, the Royal College teaches conservation techniques, history, the systematic knowledge of materials, standardized methods, and hands-on practice, through which its students become certified as conservators.

Superficial differences such as the certification of conservators and the education system are important. However, what is more important is that higher education in Denmark emphasizes the acquisition of common terms and jargon [15]. A common understanding of intangible information such as know-how and background is facilitated by the systematic reintegration of its process, decomposed elements, restrictions, and the like, and this makes it possible for human thoughts and cooperation to predict the unknown.

5.3. System of Work that Shares Tacit Knowledge

In Japan, the practice of conservation does not require certification and typically depends on the experiences of contractors. Craftsmen in charge of restoration practice their craft by repeatedly prototyping based on their own know-how. However, there is a problem in that they are not given the responsibility to produce a faithful reproduction based on documents and data on the environment of the time, meaning, techniques, etc. [3].

In Japan, the manufacturing industry has a "multiple subcontracting structure." Because contract companies do not get directly involved with end-users and the market, their overall goals and responsibilities tend to easily become unclear.

In Denmark, most certified conservators are engaged in conservation work. Using a common language of conservation fostered by higher education, they strengthen the network of conservators, refer jobs to each other, improve the quality of the work via their multilateral points of view and cooperation, and pursue independent studies and publications.

In Denmark, the "Law of Jante" (Janteloven) has been followed for many years. It advocates respect for individuals, but warns against self-righteousness based on the belief that priority should be given to the overall optimization of groups in order to bring benefits to individuals.

The self-independent, cooperative work style of conservators has likely been influenced by this discipline.

5.4. Chemistry Between Technology and Tradition

The automation of traditional craftsmanship arouses particularly strong resistance and skepticism against changes to familiar procedures.

However, when application of the Tacit Knowledge Sharing System co-designed in Japan (presented in Section 4.1) was suggested, the craftsmen did not show much resistance or skepticism, and they even gave independent requests and suggestions. This indicates the possible benefit of automation based on the two viewpoints, such as "the substitution of machines for humans" and "the reinforcement of the human ability that it is difficult to be replaced by machine," for traditional craftsmanship.

The survey in Denmark presented in Section 4.2 indicates pride in the acquisition of systematic knowledge and techniques related to conservation, and an emphasis on manual work and on-site experience. These facts do not imply that craftsmen are completely free of resistance to the introduction of automation.

However, as presented in Section 2.3, Denmark acknowledges the need for scientific investigation – more than any other country – and also recognizes the importance of cooperative work. Thus, it has predicted that the introduction of automation that enhances human abilities will be relatively easy. Denmark applied automation that enhances human abilities before any other country for the purpose of cultural heritage. For instance, the Jorn Museum introduced an interactive work system that provides an experience of the famous block print technique, thus enabling the sharing and inheritance of techniques accompanied by tacit knowledge.

6. Conclusions

This study presents the following conclusions:

i. Definition of Framework of Conservation Technique Inheritance

As a result of a comparison of European and American work regulations on conservation, it was found that these work regulations included the tacit knowledge to be inherited in the techniques of conservation. Based on prior work regulations, a framework of conservation technique inheritance comprised of eight items of tacit knowledge was defined as shown in **Table 2**.

ii. Visualization of Human Abilities at Worksites

Using the framework of conservation technique inheritance, the tacit knowledge of conservation techniques

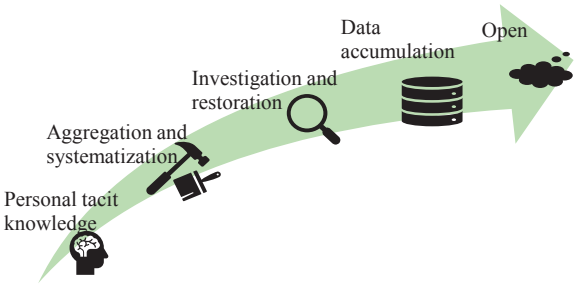

Fig. 3. Steps for opening conservation techniques in Denmark.

were extracted and visualized based on codes recorded through ethnographical inquiry in Japan and Denmark.

We noted that under the influence of a multiple subcontracting structure, conservation techniques in Japan are scattered as tacit knowledge and tend to be closed and restricted. We also confirmed that under the influence of the "Law of Jante" (Janteloven), conservation techniques in Denmark are followed through a traditional education system and inherited through cooperative work by certified conservators, and tend to be more open than those of Japan.

iii. "Tacit Knowledge Sharing System" Built by Co-Design

In the case study of Japan, we built a Tacit Knowledge Sharing System together with the craftsmen. As a result, it was indicated that the valuable tacit knowledge for which comments such as "I do not want to teach" and "It is impossible to verbally express this" apply can be shared through documents, photos, videos, and OJT. Inspired by videos of each other's work, the craftsmen intended to utilize the system and share tacit knowledge in human resources to foster work cooperation. We successfully verified that automation that enhances human abilities can make craftsmanship more open.

iv. Automation for Inheritance of Valuable Human Abilities Based on Comparison Between Japan and Denmark

The method for opening up conservation techniques in Denmark (see **Fig. 3**), the common language [15], the work regulations (see **Table 2**), and the way of working (see **Table 7**) were useful references in designing the conservation technique inheritance methods in Japan, which was restricted by unsociable customs. It will be difficult to introduce work regulations and a certification system into Japan immediately. However, mutual understanding and cooperation between craftsmen, their colleagues, and their clients will be promoted by the consciousness of the framework of conservation technique inheritance defined in this study. This framework will help with the inheritance of the craftsmanship and cultural properties.

In addition, it was found that the experiment on the Tacit Knowledge Sharing System in Japan could be a reference point for an automation system for the conservation technique inheritance in Denmark, which follows a traditional education system.

Because the history, system, and work environment are quite different between Japan and Denmark, an equal comparison is difficult. However, this study successfully grasped a variety of behavior and recognition and indicated an important awareness of automation. If automation to reinforce a human ability that it is difficult to replace by a machine is supplemented by traditional education, more human abilities will be passed down to future generations in a more exact manner.

We are glad that this study will be of some help in passing on conservation techniques, promoting the appropriate use of automation, and ensuring the inheritance of cultural properties.

References:

[1] KADK, "Evaluation fo the Research at the School of Conservation," Final Report, 2002.

[2] "The Royal Danish Academiy of Fine Arts," https://kadk.dk/en/ [Accessed Septempber 30, 2017]

[3] H. Otake and Y. Futagami, "Training for a coservator-restorer in western countries: Qualification of "restorer of cultural properties" in Italy," Science for conservation, Vol.43, pp. 133-145, 2003 (in Japanese).

[4] J. Blomberg, J. Giacomi, A. Mosher, and P. Swenton-Wall, "Ethnographic Field Methods and Their Relation to Design," Participatory Design: Principles and Practices, D. Schuler and A. Namioka (Eds.), pp. 123-155, L. Erlbaum Associates, 1993.

[5] R. Legard, J. Keegan, and K. Ward, "In-depth Interviews," Qualitative Research Practice – A Guide for Social Science Students, J. Ritchie and J. Lewis (Eds.), Chapter 6, pp. 139-169, Sage Publications, 2003.

[6] F. Kensing and J. Blomberg, "PD: issues and concerns," Computer Supported Cooperative Work, Vol.7, pp. 167-185, 1998.

[7] S. Hirata, "An emprical study of value creation of multi-product small-volume production through industry-academia collaboration," Proc. of IEEE IEEM2017, IEEM17-P-0541, 2017 IEEE Int. Conf. on Industrial Engineering and Engineering Management, Singaopre, 2017.

[8] S. Miura, "On Code of Ethics," Bunkazai Hozon Shufuku Gakkaishi, Vol.55, pp. 1-6, 2010.

[9] J. Blomberg, M. Burrell, and G. Guest, "An ethnographic approach to design," The human-computer interaction handbook, J. A. Jacko and A. Sears (Eds.), L. Erlbaum Associates Inc., pp. 964-986, 2002.

[10] S. Hirata and H. Osada, "Analysis of Work Style in Operation & Maintenance of Information System," Proc. of IEEE IEEM2009, ISBN:0-7803-8741-4, IEEM09-P-1091, 2009 IEEE Int. Conf. on Industrial Engineering and Engineering Management, Hongkong, 2009.

[11] S. Hirata, "Requirement development and project management by ethnography," Introduction to Strategic Technology Management 4 – Chapter 3, Tokyo: Fuyo Shobo Publication, pp. 77-113, 2016.

[12] S. Hirata, "Human resource development project for services by ethnography," The 4th Int. Conf. of Serviceology Proc., 2016.

[13] P. Ehn, "Work-Oriented Design of Computer Artifacts," Erlbaum, 1988.

[14] M. Yasuoka, "Collaboration Support in the Initial Collaboration Phase," Proc. of Participatory Design Conf. 2006, Vol.2, pp. 129-132, 2006.

[15] M. Yasuoka, "Collaboration across professional boundaries – the emergence of interpretation drift and the collective creation of project jargon," J. of Computer Supported Cooperative Work, Vol.24, No.4, pp. 253-276, 2015.

[16] J. Greenbaum and M. Kyng (Eds.), "Design at Work" Cooperative Design of Computer Systems, Lawrence Erlbaum, 1991.

[17] D. Schuler and A. Namioka, "PD: Principles and practices," Erlbaum, 1993.

[18] M. Yasuoka and T. Ohno, "Impact of Constraints and Rules of User Involvement Methods for IS Concept Creation and Specification," Proc. of the 6th Scandinavian Conf. on Information Systems, Scis 2015, Oulu, Finland, August 9-12, pp. 220-236, 2015.

[19] M. Yasuoka, M. Nakatani, and T. Ohno, "Towards culturally independent participatory design method," 2013 Int. Conf. on Culture and Computing, pp. 92-97, 2013.
[20] M. Yasuoka, K. Kadoya, and T. Niwa, "Introducing a game approach towards IS requirements specification," 2014 47th Hawaii Int. Conf. on System Sciences (HICSS), pp. 3687-3696, 2014.
[21] J. Kawakita, "An Idea Development Method," Chuokoron-sha, 1967 (in Japanese).
[22] J. McGonigal, "Reality is Broken, Why Games Make Us Better and How They can Change the World," Penguin Books, 2011.
[23] A. Fleury, "Drawing and acting as user experience research tools," APCHI, pp. 269-278, 2012.
[24] S. Titta, K. Mehto, T. Kankainen, and V. Kantola, "Drama and user-centered methods in design," Inclusive Design, pp. 5-8, 2005.
[25] A. L. Strauss and J. M. Corbin, "Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory," Sage Publications, 1998.
[26] K. Charmaz, "Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis," Sage Publications, 2006.
[27] H. Kiumura, "Developing Innovative IT-based Full Mold Casting," Int. J. Automation Technol., Vol.2, No.4, pp. 289-296, 2008.
[28] M. Fukihara, H. Makino, and K. Hashimoto, "Automation in Green Sand Processing Equipment," Int. J. Automation Technol., Vol.2, No.4, pp. 80-84, 2008.
[29] K. Terashima, T. Miyoshi, and Y. Noda, "Innovatie Automation Technologies and IT Applications of the Metal Casting Process Necessary for the Foundries of 21st Century," Int. J. Automation Technol., Vol.2, No.4, pp. 229-239, 2008.
[30] Y. Nagasaka, "Automation and Process Management in Foundry," Int. J. Automation Technol., Vol.2, No.4, pp. 266-275, 2008.

Name:
Sadayo Hirata

Affiliation:
Associate Professor, Shibaura Institute of Technology

Address:
3-9-14 Shibaura, Minato-ku, Tokyo 108-5848, Japan

Brief Biographical History:
1987- Joined Fujitsu Limited
2010 Ph.D. from Tokyo Institute of Technology
2011- Visiting Associate Professor, Hosei University
2013- Associate Professor, Shibaura Institute of Technology

Main Works:
• "Quality management model realizing the co-evolution between the technology development and the market," J. of The Japanese Society for Quality Control, Vol.36, No.4, pp. 490-501, 2006.
• "Analysis of the communication in requirement management of information system," J. of The Japan Association for Management Systems, Vol.26, No.2, pp. 91-97, 2010.

Membership in Academic Societies:
• Science Council of Japan (SCJ), Member
• Society for Serviceology (SfS)
• Japan Society for Research Policy and Innovation Management

Name:
Mika Yasuoka

Affiliation:
Research Associate, DTU Management Engineering, Technical University of Denmark

Address:
Centrifugevej, 2800 Kgs. Lyngby, Denmark

Brief Biographical History:
2003- Research Center for Advanced Science and Technology, The University of Tokyo
2006 Ph.D. from IT University of Copenhagen
2009- IT University of Copenhagen
2015- Technical University of Denmark

Main Works:
• "Collaboration across professional boundaries – the emergence of interpretation drift and the collective creation of project jargon," J. of Computer Supported Cooperative Work, Vol.24, No.4, pp. 253-276, 2015.
• "Impact of Constraints and Rules of User Involvement Methods for IS Concept Creation and Specification," H. Oinas-Kukkonen, N. Iivari, K. Kuutti, A. Öörni, and M. Rajanen (Eds.): The 6th Scandinavian Conf. on Information Systems 2015, LNBIP 223, pp. 220-236, Springer, Heidelberg, 2015.