Skill Ontology for Mechanical Design of Learning Contents

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***Abstract*—In recent years, the effect of globalization environment, and the aging of engineers and skill workers have tremendously changed the manufacture industry, therefore, transfer of technology and skill has become a very important issue. Parallel with the advancement of the Internet, e-learning systems stress on the learning of knowledge, skill transfer is rarely mentioned. In this paper, we propose a skill ontology that consists of metadata and relationships among metadata. With the skill ontology, the document can be shared, inter-operated and thus increase the efficiency of learning process.**

***Index Terms*—skill ontology, mechanical design, metadata, learning contents**

I. INTRODUCTION

In recent years, the on-going globalization, and the aging of engineers and skilled workers have caused the problem so-called "hollowing out of industry" that is strongly changing the environment surrounding manufacturing industry. In Japan, measures such as the transfer of technology and skill are taken to cope with the situation of hollowing out, where by focus has been laid on the training of highly skilled workers. Corresponds to the rapid development of information technology, particularly the Internet environment, many enterprises are implementing e-learning system in their personnel training program, with the purposes of cutting cost and obtaining better training outcome. No doubt, in e-learning system, the design of learning contents is very essential in achieving these purposes. Learning contents is defined as a gathering study objects [1][2]. The concept of study object is extensive, which includes learning needs, learning processes, and learning objects and so on. When designing these contents, it is necessary to lay attention on luring out the learners' desire, and to enable learners to absorb the knowledge in an effective and efficient manner.

In this paper, we study on the systematization of learning contents of in mechanical design. Mechanical design is one of the activities that require creativity and intelligence in both knowledge and skill. Knowledge is something that can be gained from verbal contents while skill requires practice and experience for one to master it. In mechanical design, acquiring both knowledge and skill are equally important, lacking of one of those may not have produced a compatible personnel.

Conventional e-learning system is often thought to be inferior then current academic schooling system or corporate training program as it lacks of on the spot training, which is essential for skill development. However, with the advancement in information technology, the restriction of on the spot training can gradually be overcome through providing of multimedia content and interactive e-learning system.

Regarding systemization of mechanical design skill, we propose a skill ontology that can be understood by the computer. Ontology is a specification of a conceptual-ization or a description of concepts and relationships that can exist for an agent or a community of agents [3]. By having the ontology of mechanical design skill, user of e-learning system is able to master the design skill in a more effective and efficient way, thus achieving the purpose of producing high-quality personnel.

II. RELATED WORK

Generally, for e-learning system, SCORM(Shareable Content Object Reference Model) has been the standard of learning contents decided by ADL(Advanced Distributed Learning Initiative)[4]. The purposes of the standard are to enable inter-operability and reuse of learning contents. By following the standard, system designer may describe the learning processes such as "If the learner fail in passing the exercises, then present learning contents for review " or "Repeat explanation and the problem until the learner achieves the learning target".

In recent years, many researches regarding e-learning contents had been carried out, with Learning Object Metadata (LOM) [5] being the most influential standard determined by Learning Technology Standardization Committee of IEEE [6]. Jan & Wolfgang [7] and Ljiljana

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& Steffen & Rudi [8] and Nicola & Peter & Wolfgang [9] and Marilyn [10] and Rego et al [11] had stated clearly the use of ontologies and metadata for e-learning and its working mechanism. Later, some authors like Katrien et al [12], and Pamela et al [13] had proposed some new sets of ontology to suit different purposes. As for the purpose of skill transfer, Thorsten and York [14] had introduced an ontology-based skill management for large insurance company.

With all these researches, learning contents of e-Learning has been pushed towards practicality. Nevertheless, most of the researches had centered their learning contents on knowledge education. Contrary to the field of mechanical design and manufacturing that is undergoing evolution towards higher accuracy, more minute, and high performance, it is important to train a personnel with a wide range of knowledge and skill that consists of creativity skill and design skill. In short, it is important to recognize that knowledge and skill do not stand independently, but inter-dependently with one supplementing one another.

Figure 1 shows the comparison of our proposed skill study process and past skill study process. Nowadays, with the advancement of computer performance and broadband network, developing e-learning system that offers supreme function and multifunction is made possible. For example, by having inter-operability of contents using metadata, learners can access to various systems and absorb the skill provided from different sources, and with user-friendly authoring tools, the learning contents can be arranged in various patterns to suit different users. Moreover, with the advancement of information technology in network environment, the on the spot feeling can be conveyed in a more precise and accurate manner. This feeling is especially important in learning tacit skill as it helps learner to remember and master the skill involved. In short, the present advancement in information technology has managed to develop an e-learning that focus not only on design knowledge but also design skill.

III. SKILL METADATA FOR MECHANICAL DESIGN

As mentioned earlier, skill learning is indispensable in the study of the mechanical design. By setting metadata and systematizing of design skill, a user may acquire the knowledge and skill needed for mechanical design in a more efficient way. Corresponds to this, setting of metadata for sharing and reusing of information is one of the most vital subjects to be studied.

In general, metadata is defined as structured data about data. The development of the metadata has been actively carried out nowadays, for instance, Dublin Core Metadata Element Set is proposed to describe the information resources in terms of author of the document, title, and bibliography information, and so on [15]. On the other hand, PICS (Platform for Internet Content Selection) enables labels (metadata) to be associated with Internet content [16]. It was originally designed to help parents and teachers to control children from accessing into menace contents of the Internet, and also to facilitate the use of metadata, including code signing and privacy control. To fully promote the use of metadata description on the Internet, RDF (Resource Description Framework) has been developed for standardizing the metadata description methods [17]. With the existence of metadata rules in the Internet, appropriate and accurate information can be extracted for the users, thus promoting the inter-operability and sharing of information. The advancement in research of metadata has helped to develop a lot of metadata that serves different purposes. In determining the metadata, it is important to select simple and well-known existing words. For instance, in Dublin Core metadata, the well-known word, such as title, author, data

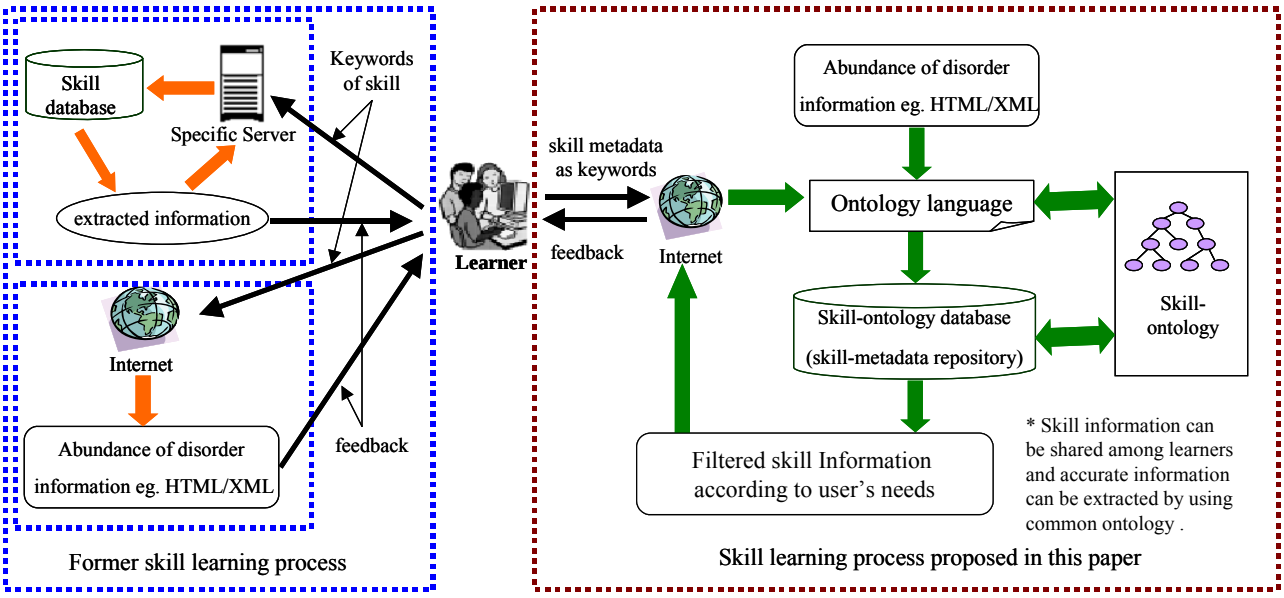

Figure 1. Comparison of our proposed skill study process and past skill study process

and etc has enable inter-operability, and promote the use of it in the Internet.

Skill metadata is data concerning skill data. Skill involves human movements and sensations that could not possibly be obtained by simply resolving knowledge in details. Therefore, skill metadata will have to reflect the nature of skill and able to lead the user to appropriate information. By having a standardized skill metadata a more practical and reliable environment can be created for searching skill information, thus assisting the user to gain skill in a more efficient manner.

A. Definition of skill metadata in mechanical design

Skill metadata is unique for different fields of study. For instance, in language study, skills can be divided into four basic categories, such as reading, listening, writing, and speaking, and when these skills can be further classified into details, such as teaching method, learner qualification and the experience and so on. Mechanical design has its own categories of skill and to identify these categories, it is important to first understand the nature of mechanical design.

Mechanical design is an intellectual activity that requires one to have creativity in producing a new design based on user needs. During the design process, designer has a high degree of freedom in deciding design parameters, and thus he is required to make wise decisions at all time. Nevertheless, the high degree of freedom may cause the designer to make mistakes easily, it is important for learner and design object to overcome time and space constraints, enabling learner to directly see and learn the skill on how a mistake can be avoided and to train up his decision making ability. For this, we propose a set of skill metadata from the aspect of ontology that consists of degree of importance, experience, description, know-how and multimedia as shown in Table 1. With the metadata, the mechanical design skill is systematized by using ontology technology and thus enabling the sharing and reuse of mechanical design skill on the Internet platform. The use of ontology will be explained in Chapter 4.

B. Explanation of defined skill metadata

Among the skill metadata degree of importance, description and skill learning method are components that are relatively easy to understand, and theirs definitions are stated in Table 1. Hereafter, we explain the metadata of experience, know-how and the multimedia, which are vital in gaining mechanical design skill.

The existence of experience greatly affects the outcome of a design work. For instance, in metal casting, the lack of experience in designing the shape, dimensions and position of irrigation may cause defects such as internal porosity and shrinkage. Meanwhile, experience in placing chill plate too is important as the too small-size chill plate may not produce apparent result and too big-size chill plate may cause defects such as cold shut and hot tear or crack. From the above, it is apparent that experience plays an important role in skill development, as it is proportional to tacit knowledge gained through the process of involvement. Although not easy, if a certain degree of tacit knowledge can be past down to the learner through the e-learning system, e-learning system may become one of important tools in skill transfer.

Know-how in mechanical design is a very subjective skill that strongly depends on personal experience, where by it contains of tacit knowledge. Here, tacit knowledge refers to skills that are incubated by individual and it can hardly be described in words [18]. In most of the time, tacit knowledge consists of human sensibility in which sensibility is described as “awareness of and responsiveness toward something” in the dictionary. On the other hand, human being has five senses namely, sight, hearing, smelling, tasting, and touch. By activating these five senses and as time flows by, tacit knowledge can be acquired or created. In the process of the mechanical design that composes of concept creation and designing, skill is gradually developed through human sensibility and five senses, which are included in our proposed metadata.

The initial stage of mechanical design is to have a concept. The creation of concept can sometimes be

Table 1. Definition of skill metadata for mechanical design

Skill metadata	Metadata refinements	Define and comment
importance	grade	The metadata concerning the degree of importance the skill offered to the learner for skill acquisition, and is possible to divide into such as grade if subdivide.
experience	qualification year	The data concerning experiences of the skill, includes the qualification and the period of time involved with the skill.
description		The data that explains the content of the skill.
know-how	sensibility five senses	Data concerning know-how of skill. Know-how here indicates the skill obtained from the process of mechanical design by not the one having made it for the manual by documents but senses and sensibility.
multimedia		The comprehensive utilization of medias in skill expression, it is a combination of the data of digitalized images, voices, and characters, etc.

sensible on top of responsibility, satisfaction, curiosity and so on, the concept drawing drawn by each individual may be very different. Moreover, the creation of concept can be stimulated by other concepts, for instance, when a designer sees a certain shape, he can relate the shape to new design or try to modify the shape. The same cycle can also happen on other five senses where by stimulation on them can bring out new creation and also new skill.

The next stage after concept development is design stage. Design is the process of making decisions on design parameters such as attribute, state, behavior, and function in a systematic and detail way [19]. Again, to be able to perform a good design job, one needs to master both explicit and tacit knowledge. Here, tacit knowledge refers to skill of designing attribute, state, behavior, and function through five senses.

Attribute can be considered as the geometrical, physical, scientific and mechanical characteristics of a design object. Among the common attributes are the dimensions, color, and surface textures of a product. For mechanical design, in order to achieve certain attributes, skill is required. For instance, in metal casting, malleable iron is normally used. When pouring the liquid metal, the Chemical composition， Cooling speed， pouring temperature may easily causes imperfect graphitization, metal penetration, fissure and rough surface, affect the color, texture of the work piece. Producing a good work piece may need visual and touch skills, that are important for learner to master.

State is a set of the attributes values of design object at a particular time and place. As design object is composed of a combination of parts, connection betweens these parts at particular time and place is considered as the state of design object. By having state as metadata, learner can have a better idea on the design process and learn the insight of mechanical design.

Behavior is a transition of state. By having this metadata, information that consists of video and audio material can be extracted, and allow the learner to have a much more clearer picture on how the mechanical design is been carried out.

Function is the nature of work performed by design object originated from designer intentions. In mechanical design, function includes actions such as changing, bonding, energy transferring and so on. By having function metadata learner can learn about the main jobs of a machine is more direct way, and hopefully, the skill to plot out the function can be gained in an efficient method.

Multimedia is among the most important metadata in skill learning. Under the e-learning study environment, there are learning material of all kinds, which includes 3D CAD, voice and image (CD, DVD) and homepage text, VR (Virtual Reality) spaces, haptic device and so on. As VR technology has improved tremendously in recent years, learner may soon experience the design process in the virtual space, thus gaining on the spot operation experience that helps to develop his design skill. Additionally, sound, voice, and image at the design spot may be a good way of conveying tacit knowledge. For instance, the selection of material and tool may be decided by listening to the sound of machining. By reserving this sound and image, it helps to improve the skill of learner without having the learner to really experience this at the operation spot. In recent years, haptic devices that can replay the somatic sensation mainly composed of sense of touch and sense of force is gaining attention, especially in the field of skill transfer. With this, skill that includes feeling of weight, surface texture, and handwriting can be acquired through an e-learning system.

What important here is that although the skill expression provided in the network environment may still not be enough to express the actual site experience at current time, the advance in information technology may form a more realistic learning environment that enable learner to gain important tacit knowledge in the mechanical design in the future. Therefore, it is important and worthy to have metadata related to mechanical skill for the purpose of skill acquisition on the Internet.

VI. PROPOSAL OF SKILL ONTOLOGY IN MECHANICAL DESIGN

After determining the important metadata for mechanical skill, the relationships among metadata or on the whole called as ontology is proposed.

A. Relationship between metadata

In the ontology, two types of relationships exist between metadata, namely, part-of relationship and association-of relationship. With the part-of relationship, the mechanical skill can be arranged in a hierarchy format, in which the lower metadata is part-of the upper metadata. On the other hand, the association-of relationship indicates that two metadata are somehow inter-related however not as part-of relationship. It nearly explained association-of relationship between the skill metadata in Section 3.2. Figure 2 shows the skill ontology diagram of mechanical design. In this figure, the contents related to sensibility and five senses metadata can be expressed by using multimedia, hence, these metadata are put as associate-of relationship.

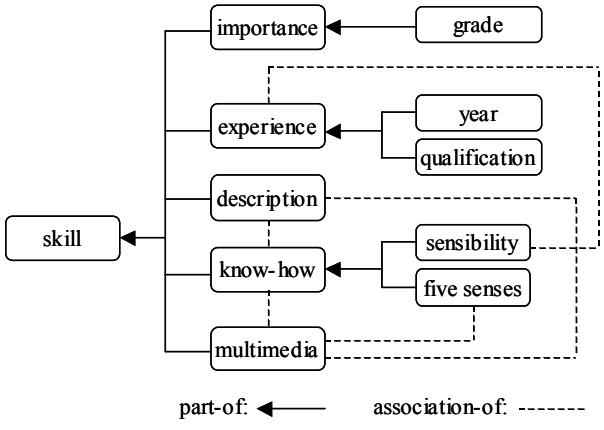

Figure 2. Skill ontology for mechanical design

B. Description of skill ontology in mechanical design

RDFS(Resource Description Framework Schema) is an language used to define ontology. With RDFS document, the skill ontology can be shared and inter-operate among users in the Internet. RDFS is written in XML(eXtensible Markup Language) syntax, where the relationships such as hierarchy relationship and inter-related relationship among metadata can be made clear. The description procedures of ontology are stated as follows.

(1) Describe of version information.

(2) Specify the name space used by ontology.

(3) Describe the relationships between the metadata.

For skill ontology, the name space URI can be written as http://www.xxx.example.co.jp/schema/sk #. Using the namespace function of XML, the respective 14 skills metadata with the prefix of (sk:) in general is used. For example, sk: importance, sk:experience, sk:know-how, and so on.

As shown in Figure 3, the internal and the shape of the part are expressed in 3D CAD drawing. The skill involved to produce the shape of the product can be laterally displayed together with the drawing. List 1 shows the description of skill ontology concerning Figure 3 by using ontology language. The first line in List 1 describes the version information. The 3~7th line declare rdf, and rdfs. Dc and the sk name space. The description element of the RDF element inside shows the resource to be embedded. In the ninth line, the about-attribute indicates the resource concerning Figure 3. Finally, lines of 13 and below are statements that explain information on the skill metadata of the resource.

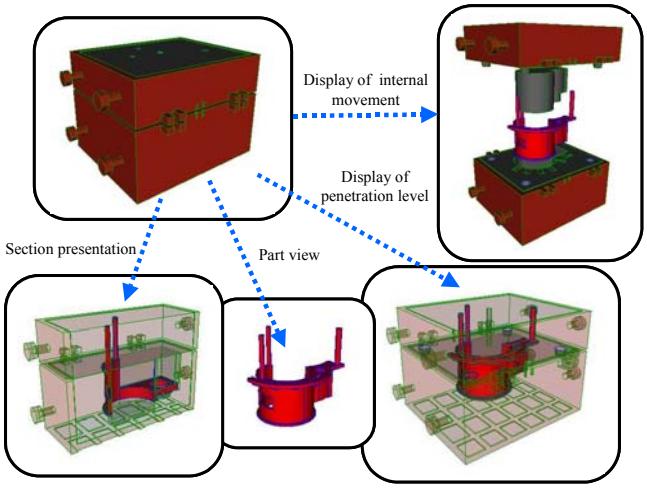

Figure 3. A case box design using 3D CAD

V. APPLICATION OF SKILL ONTOLOGY IN E-LEARNING SYSTEM

Figure 4 shows the application of skill ontology in looking for appropriate learning contents for learner. The explaination for a, b, and c parts indicated in the figure are stated as below.

List 1. Description of skill ontology for Figure3

```
<?xml version='1.0'?>

<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns# "
   xmlns:rdfs= "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc= "http://purl.org/metadata/dublin_core#"
   xmlns:sk ="http://www.xxx.example.ac.jp/schema/sk#">

   <rdf:Description rdf:about=
                "http://www.xxx.example.ac.jp/skill01">
     <dc:title>A cast box design of casting by using 3DCAD
     </dc:title>
   </rdf:Description>

   <rdf:Description ID=" A cast box design of casting by using
                          3D CAD ">
     <sk:importance>
       <sk:grade> The cast designis important for learner and
                  the degree of important is high.
       </sk:grade>
     </sk:importance>
     <sk:experience>
       <sk:qualification>Fundamertal examination for
                         mechanical design engineer
       </sk:qualification>
       <sk:year> The third grader level of 4-year university
                 mechanical engineering course
       </sk:year>
     </sk:experience>
     <sk:description>Expression of internal and external shape
                     of metal cast product design by 3D CAD
      </sk:description>
      <sk:contents>
        <sk:five-senses>
          <sk:design>Expression of shape, color and material
                     feeling of metal cast product, expression
                     of the arrangement between products,
                     expression of change of connection and
                     relation, display of section, and expression
                     of seeing through level.
          </sk:design>
        </sk:five-senses>
      </sk:contents>
      <sk:multimedia>3D CAD is skill for technical expressions
      </sk:multimedia>
    </rdf:Description>
   </rdf:RDF>
```

a. In the Internet network, learner searches his/her wanted learning contents by keying in keywords under appropriate metadata categories.

b. Keywords from above is then extended to related keywords by skill ontology parser. Next, the HTML/XML webpages that contain all the related keywords are then searched in the Internet, in which some of the webpages may contain RDFS document written in skill ontology. The priority of those documents are then arranged refering to the original keywords input and the skill ontology. By having the above, accurate and appropriate documents are provided to the learner, in which learning process can become more effective and efficient.

c. Here, we show how the skill of designing mechanical power transmission system can be learned through a skill learning support system. After the learner has key in related keywords such as “gear design” or “power transmission”, the material extracted from the Internet may contain learning material in the forms of video clip and text. By using SMIL(Synchronized Maltimedia Integration Language) technology [20], drawing, audio file and video clip file can be executed simultaneously. During the playing of video clip, the learner can access to other related material by clicking at the video image. With this kind of system, learners who have different degree of knowledge can gain their skill and knowledge in their own way and thus increase the learning efficiency for each learner. On top of this, by attaching RDFS metadata linking onto the SMIL document, the searching of relevant material can become more accurate. In the example of designing a mechanical power transmission system, the rib of the gear manufactured through machining and metal casting is varied. For machining method, the rib is usually thinly machined in order to achieve lightweight. However, for metal casting method, the rib cannot be made too thin as this would affect the metal flow and may easily causes defect. By having video clip to explain the above situation, learner can understand the limitation of both methods and pay attention to parts A, B, and C. Moreover, by having transfer method asmetadata, learner can extract 3D CAD drawing from the Internet and learn about making drawing directly.

V. Conclusion

In this paper, based on the fact that skill development is vital in the field of mechanical design, we have defined a skill metadata of mechanical design, and have systematized the mechanical design skill based on ontology technology. In addition, we have also discussed how tacit knowledge can be expressed in e-learning environment. With this, we hope this will contribute to skill education of mechanical design learning contents as a result and expect further discussion about this problem and greater progress in the theory and technology in this field.

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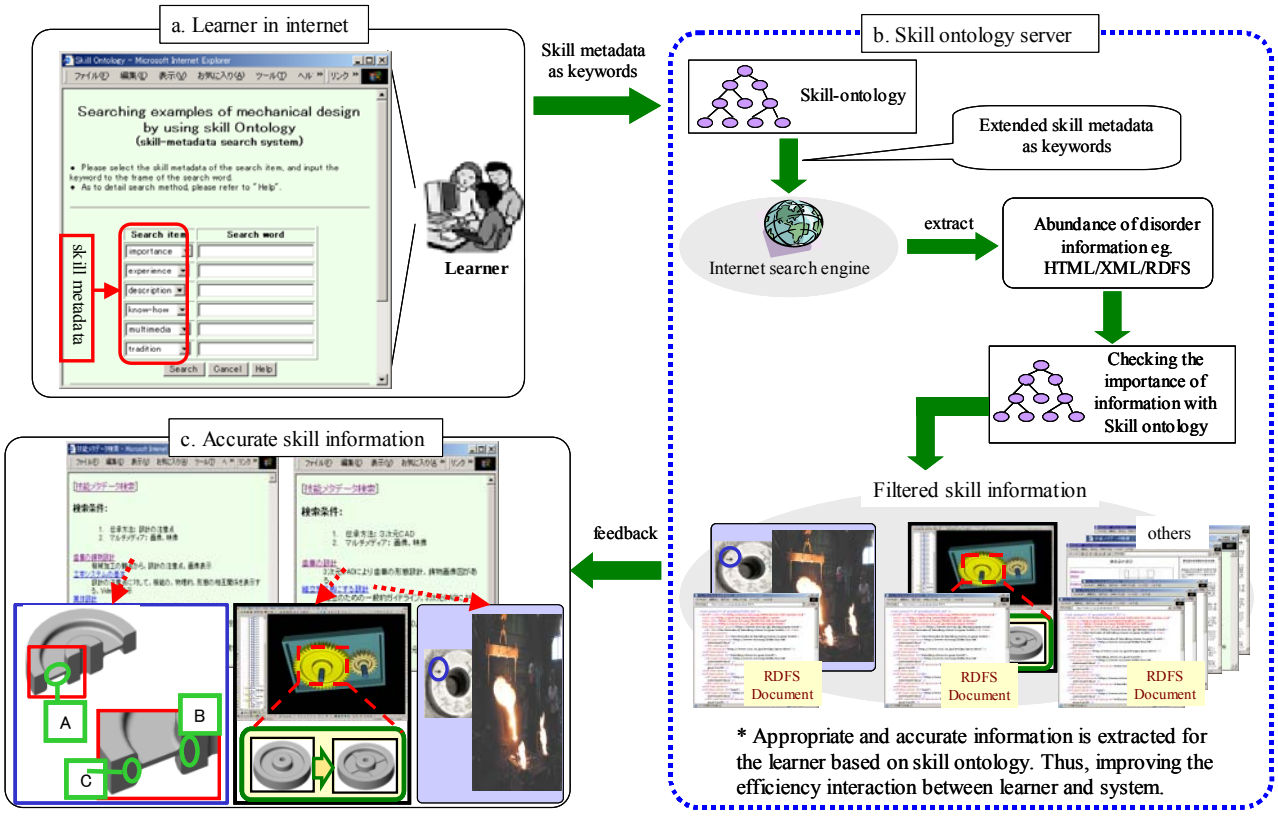

Figure 4. Application of skill ontology for mechanical design learning contents

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