A Problem-Solving Process Model for Learning Intellectual Property Law Using Logic Expression: Application from a Proposition to a Predicate Logic

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Abstract. We have previously proposed a problem-solving process model using logical expressions, based on the observation that legal statements can be described using logical expressions when considering the problem-solving process model used by engineering students in the study of law. However, propositional logic alone has a limited range of application to practice problems, and so here we examine the description of practice problems using predicate logic by extending propositional logic to first-order predicate logic, and consider the effectiveness of this approach.

Keywords: Problem-solving process · Learning of intellectual property law · Predicate logic

1 Introduction

More than a decade has passed since the establishment of the Intellectual Property Basic Act in Japan. During this time, the pace of globalization has intensified and there are increasing opportunities for foreign companies to operate in Japan. In this context, industry has expressed a desire that students acquire basic knowledge of intellectual property while at university, but the adoption of education in intellectual property law is still far from adequate [1]. Although engineering departments recognize the importance of intellectual property training, it has been difficult to establish many lectures on intellectual property because of its relationship with other courses. In a survey that we conducted looking at the syllabi of engineering departments in universities around Japan, we found that about two academic units (30 h of class time) is the best that can be managed, and there were also cases where several hours were allocated to teaching intellectual property as part of ethics courses [2–4]. Thus, an

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important question is whether it is possible to prepare teaching materials to enable students to efficiently learn intellectual property law while also raising their motivation to learn. Against this background, we have developed an e-learning system for intellectual property law as a study support system to enable students to study on their own outside of regular teaching hours for the two academic credits (30 h) of intellectual property law coursework offered by engineering departments.

In this paper, we first analyze the relationship between the frequency with which students use our developed system and their motivation to learn. We then propose a problem-solving process model for engineering students learning intellectual property law. The learning system utilizing this model is still under development but involves the use of logical expressions to represent legal articles in intellectual property law so that solutions can be derived automatically by a computer and feedback on errors can be provided to the students by comparing the logical expression for their entered solutions with the logical expression generated computationally and looking at the difference [2–5]. The aim of this paper is to consider how this system can be further developed to make it more suitable as a learning system for engineering students.

2 Example of Intellectual Property Law Training in an Engineering Department

2.1 Training System Used so Far

In a major offered by the engineering department of a certain university, two academic units (30 h) of classes were allocated to intellectual property law. The subject is optional and students can freely choose whether to take it. Almost none of the students have any prior knowledge of law, and so the subject matter consists of 6 h of lectures on basic law in general, followed by lectures on industrial property law (the Patent Act, the Utility Model Act, the Design Act and the Trademark Act) and copyright law over the remaining 24 h of classes. Every year, all lectures are recorded on video and made available to course participants outside class hours as an e-learning system. The lecture notes handed out in class can also be downloaded via the e-Learning System. The e-learning system is for self-study and supplementary lessons, and its use is optional.

2.2 Course Evaluation by Students

We conducted a survey (n = 53) about the 2013 intellectual property law course [6]. The survey content relevant to this section are as follows. All items were scored on a four-point scale.

(1) Motivation to learn prior to the course (1 = "none" 4 = "high")
(2) Sense of value after 30 h of lectures (1 = "none" to 4 = "high")
(3) Satisfaction after 30 h of lectures (1 = "none" to 4 = "high")
(4) Desire to continue learning after 30 h of lectures (1 = "none" to 4 = "high")
(5) How often did you use the e-learning system? (1 = "not at all" to 4 = "very often" as well as an option for "only to print out lecture notes")

(6) Evaluation of using the e-learning system (1 = "not at all useful" to 4 = "extremely useful"; only assessed for students who answered either "fairly often" or "very often" in question (5))

In relation to motivation to learn, Fig. 1 shows a comparison of the results of questions (1) and (4). Five students answered "none" before the lectures started but no student answered "none" afterward.

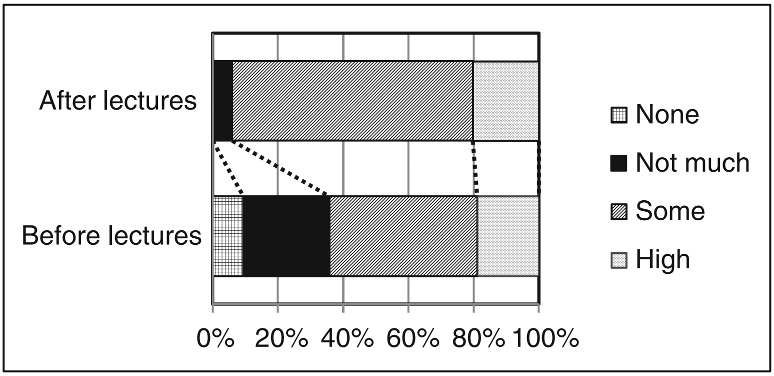

Fig. 1. Change in motivation to learn before and after lectures

As shown in Table 1, 23 students increased their motivation to learn after the lectures (the shaded cells), while 1 student remained at a low level (2→2), 25 students remained at a high level (3→3 or 4→4) and 4 students had lower motivation after the lectures (3→2 or 4→3). Overall, most students showed increased motivation to learn after the lectures.

Figure 2 shows the results for "sense of value" (2) and "satisfaction" (3).

Turning to survey question (5), we found that 43 of the 52 respondents used the system "some", "fairly often", and "very often".

Table 1. Comparison of motivation to learn before and after lectures

		Motivation after lectures				
		1	2	3	4	Total
Motivation before lectures	1	0	1	2	2	5
	2	0	1	12	1	14
	3	0	3	16	5	24
	4	0	0	1	9	10
	Total	0	5	32	17	54

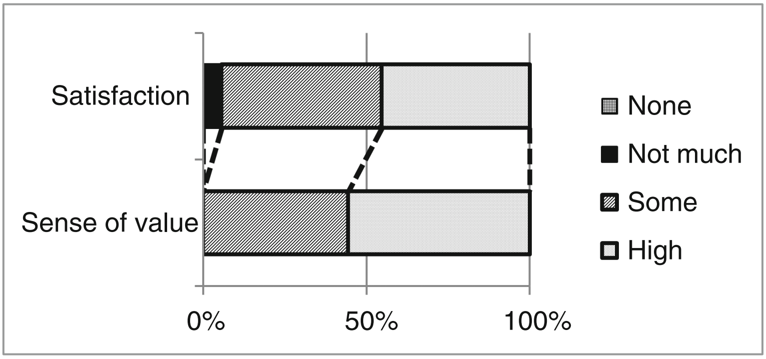

Fig. 2. Sense of value and satisfaction with the lectures

The results of survey question (6) directed at those students who used the system very or fairly often were that 20 students found the system “extremely useful” and 6 found it “somewhat useful”, while no students responded “not very useful” or “not at all useful”, indicated that the system is useful.

However, when we calculated the Spearman rank-correlation coefficient (all subsequent rank-correlation coefficients are Spearman’s) for the association between survey questions (1) to (4) and question (5) on usage frequency (Table 2), none of the correlations were significant, meaning that students who use the system often do not necessarily have high satisfaction or motivation to learn.

Table 2. Correlations between frequency of system usage and other assessments

	Rank-correlation coefficient
Motivation to learn before lectures	0.144
Sense of value	0.159
Satisfaction	0.168
Motivation to learn after lectures	0.212

Table 3 shows the rank-correlation coefficients for survey questions other than questions on usage frequency, namely, questions (1) to (4). Given that both “sense of value” and “satisfaction” are assessments made after the course completed it is perhaps not surprising that these are significantly correlated with motivation to learn after the course.

2.3 System Issues

We conducted the same survey in 2014 and 2015, obtaining very similar results [2, 3]. Summarizing these results, we found that overall the sense of the value and satisfaction with the course was high, with most students finishing the course with higher

Table 3. Rank-correlation coefficients for each pair of assessments

	Motivation before lectures	Sense of value	Satisfaction	Motivation after lectures
Motivation before lectures	1	0.401**	0.205	0.386**
Sense of value	0.401**	1	0.616**	0.599**
Satisfaction	0.205	0.616**	1	0.443**
Motivation after lectures	0.386**	0.599**	0.443**	1

Test of no correlation $*p<0.05, **p<0.01$

motivation to learn than when they began. The e-learning system that we have been operating was assessed as useful, but students who used the system often did not necessarily have high satisfaction or sense of value. As discussed above, despite the importance with which intellectual property training is regarded in engineering departments, not much time can be allocated to teaching it, and so it would be desirable to develop a system that can increase students' motivation to learn. With his in mind, we hoped to develop a system that takes into account the cognitive and problem-solving processes of engineering students.

3 Problem-Solving Process Model in Intellectual Property Law

3.1 Comparison with the Problem-Solving Process in Physics

Hirashima et al. [7] have modeled the problem-solving process in physics in three stages:

1. the process of generating a surface structure from the problem text;
2. the formalization process of generating a formal structure from the surface structure; and
3. the solution-derivation process of generating the target structure (including the solution) from the formal structure using quantitative functions.

However, problem questions in intellectual property law do not have quantitative relationships. This prompted us to define and propose a problem-solving process whereby logical expressions are used to derive solutions from formal structures [2, 5], taking advantage of the fact that legal statements can be represented using logical expressions [8].

3.2 Problem-Solving Process Model for Patent Law

The constraint structure here differs from the one in physics. Problem questions in physics have quantitative relationships. However, these kinds of relationships cannot be established for quiz problems in patent law. This means that it is necessary to define a constraint structure for deriving new information based on relationships.

There have been many studies (e.g., [8] to [11]) looking at converting legal statements into logical expressions that can be subjected to logical operations. Tanaka et al [9] found that legal statements are made up of a topic, conditions, object, content, and stipulations with the following structure:

$$\text{Topic} \wedge \text{Conditions} \Rightarrow \text{Object} \wedge \text{Content} \wedge \text{Stipulations}$$

These studies are based on the concept that legal statements have a prototypical structure and assume that legal statements can be converted into a particular structure because “Legal clauses are a form of natural language but can also be regarded as a controlled language that is employed intentionally” [10]. The goal of these studies is to use these structures in search systems for legal clauses and the like. Referring to these earlier studies, we considered that the conversion of legal statements to logical expressions could be utilized to support learning. That is, we believed that the relationships between properties in patent law can be represented using logical expressions, thereby enabling the same kind of learning support as for physics.

3.3 Example of a Logical Structure from Patent Law

Figure 3 shows the requirements for issuing a patent. The right-hand side of Fig. 3 lists clauses ① through ⑦ on which these requirements are based. Figure 4 shows how the details of how the logical expressions for clauses ①, ②, and ③ have been put together, resulting in Expression (1). Similarly Fig. 5 shows how Expression (2) is derived. Clauses ④ through ⑦ produce expressions (3) through (6), which are then combined to produce the final constraint structure in the same way as shown for expressions (1) and (2) in Figs. 4 and 5.

Clauses ④ to ⑦ can be annotated as follows:

④ Not obvious	**I**	→	$\overline{\boldsymbol{I}}$	(3)
⑤ Earliest application filed	**J**	→	$\boldsymbol{J}$	(4)
⑥ Does not harm the public interest	**K**	→	$\overline{\boldsymbol{K}}$	(5)
⑦ Description filed according to regulations	**L**	→	$\boldsymbol{L}$	(6)

and so Figure 3 can be summarized as

$$\mathbf{(1) \wedge (2) \wedge (3) \wedge (4) \wedge (5) \wedge (6) \Rightarrow \text{Patented invention}} \tag{7}$$

Consider the practice question given in Sect. 3.1, namely, “John has created a special method for treating cancer patients. (The rest is omitted)” In the practice problem, a method for diagnosing, treating, or operating on human beings should be

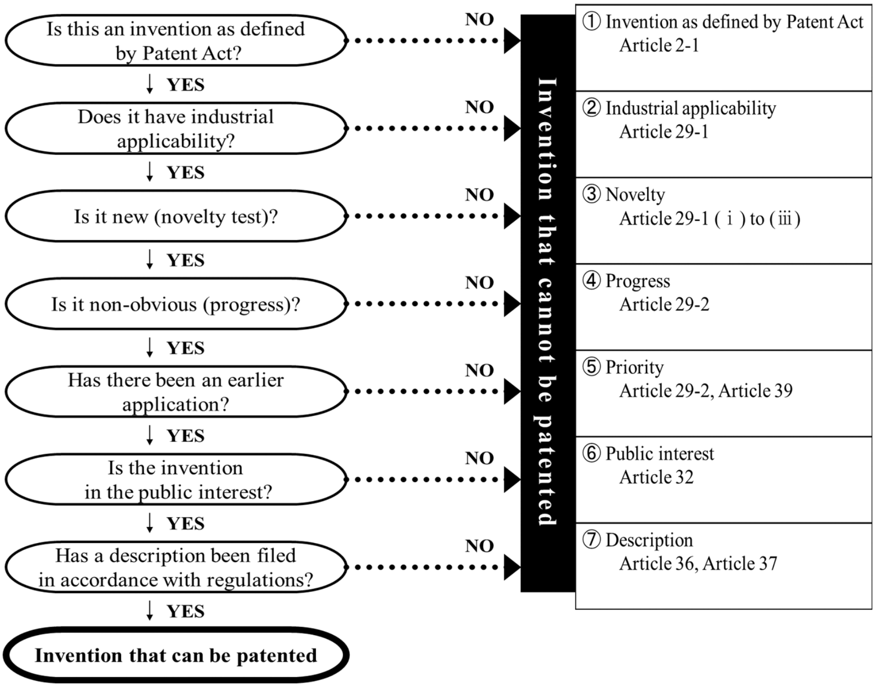

Fig. 3. Requirements for patentability

Structure of clause 2: For the purposes of this law, an invention …

Uses the laws of nature ***A***
Is a technical idea ***B***
Is a creation ***C***
Is highly advanced ***D***

↓

$$A \wedge B \wedge C \wedge D \Rightarrow \textbf{Invention} \quad (1)$$

Fig. 4. Requirements for invention

made widely available on humanitarian grounds and thus "has no industrial applicability", so we can state that the invention is not patentable (due to insufficient properties).

When answering a question on intellectual property law, a student assembles a logical expression. If the student's answer is incorrect, it is possible to work out where the mistakes are made by looking at the difference between the correct logical expression and the logical expression assembled by the student. It should be possible to create a learning support system that systematizes this approach.

Structure of Article 29-1:
An inventor of an invention that is industrially applicable ***E***
may be entitled to obtain a patent, <u>except for the following</u>:
↓
Section (i) ***F***
Section (ii) ***G***
Section (iii) ***H***

↓

$$\mathbf{E} \wedge \overline{(F \vee G \vee H)} \Rightarrow \textbf{Patented invention} \quad (2)$$

$$(\mathbf{E} \wedge (\bar{F} \wedge \bar{G} \wedge \bar{H}) \Rightarrow \textbf{Patented invention})$$

Fig. 5. Example of a requirement for patentability (Article 29-1)

3.4 Limits of Propositional Logical and Extension to Predicate Logic

The clauses discussed in the previous section can be described using propositional logic, but this approach has an issue in that clauses with relationships between concepts cannot be described. Here we consider a method for further developing propositional logic to describe legal statements using first-order predicate logic.

Unlike propositional logic, first-order predicate logic allows entities to be quantified using existence quantifiers (∃), universal quantifiers (∀), and so on. Predicate logic that allows quantification of predicates and functions in addition to entity quantification is called second-order predicate logic, while predicate logic with additional generalizations is called higher-order predicate logic. First-order predicate logic can express such things as the properties and inclusion relations of various concepts, and—in contrast to propositional logic—is capable of expressions that go inside their respective concepts.

Practice problems on legal topics often involve describing relationships between the subject and object in a way that goes inside the concept, and so by using first-order predicate logic to formalize practice problems, it should be possible to handle problems that could not be handled using propositional logic.

Legal statements have been extensively studied using first-order predicate logic since the 1980s [11]. By expressing legal statements in computer-readable code, these studies have been applied to legal expert systems, enabling legal inferences and making it to possible to check legal systems for consistency. When concepts are meticulously defined as in these studies, it seems likely that the concepts thus defined can be reused in formalizations for other problems.

However, to date there has been no research on the possibility of first representing law using first-order predicate logic (representing combinations of the legal articles to be studied) before having students studying law express their understanding using first-order predicate logic (entering this into the system) and then providing learners with feedback based on the difference between the two expressions. Moreover, the research on legal statements using first-order predicate logic that has been conducted to date does not consider the concepts and expressions used in the text of practice

in(Patent Act) ∧ def(invention, x) ⇒
def(x, technical idea) ∧ do(x, uses, laws of nature) ∧ def(x, creation) ∧ def(x, advanced
)

Fig. 6. Formalizing a clause (Article 2-1 of the Patent Act)

problems, and it will therefore be necessary to reconsider the formalizations and expression formats used in order to apply first-order predicate logic in a learning system.

Accordingly, in this study we formalize legal statements using the relationship expressions used in problem text. In this study, we refer to the functions representing the relationships between multiple concepts as "predicates" and prescribe the formalization of legal statements for the learning support system in this study as follows.

For example, Article 2-1 of the Patent Act states "'Invention' in this Act means the highly advanced creation of technical ideas utilizing the laws of nature". In this study, this formula is formalized as shown in Fig. 6.

Here x is the target creation, while in(x) indicates that this statement has full force and effect in the articles of act x. Similarly, define(x,y) indicates the relationship "x is y" and d(x,y,z) represents a predicate of the form "x does y to z." These predicates correspond to problems such as "What is …?" and "What does … do?"

We perform the same kind of formalization for problems. For example, a practice problem such as

In the Patent Act, inventions use (   )

is formalized as shown in Fig. 7.

Moreover, in response to a question such as "In the Patent Act, inventions use ( )," by simultaneously inferring the statement "An inventor of an invention that is industrially applicable may be entitled to obtain a patent for the said invention, except for the following [inventions]," we can infer that patents are for inventions and inventions use the laws of nature.

For similar practice problems based on the same pattern, we can also express the predicate using a similar format. For example, in relation to the duration of patent rights, various laws make prescriptions as follows.

- Article 67-1 of the Patent Act:
  The duration of a patent right shall expire after a period of 20 years from the filing date of the patent application.

in(Patent Act) ∧ def(invention, x) ⇒do(x, uses, y)

Fig. 7. Formalizing a practice problem

- Article 15 of the Utility Model Act:
  The duration of a utility model right shall expire after a period of 10 years from the filing date of the application for utility model registration.
- Article 21-1 of the Design Act:
  The duration of a design right (excluding design right of a Related Design) shall expire after a period of 20 years from the date of registration of its establishment.
- Article 19-1 of the Trademark Act:
  The duration of a trademark right shall expire after 10 years from the date of registration of establishment of such right.

Suppose that here we establish a function called "Term", for example, and that this function is a predicate indicating that *x* (the duration of patent rights) is the period starting from *start* (the date when the patent was filed) and until *end* (a period of 20 years), then such a predicate expression can be represented as shown in Fig. 8.

Term(*x*, *start*, *end*)

Fig. 8. Predicate expressing the term of duration

By extending propositional logic to first-order predicate logic in this way we can expect to be able to handle a greater number of different types of problems using various formalizations or combinations of formalizations.

3.5 Potential for Improving Understand Through Logical Representations

These kinds of logical expression relationships seem likely to come naturally to engineering students, and when we asked 17 students taking classes in intellectual

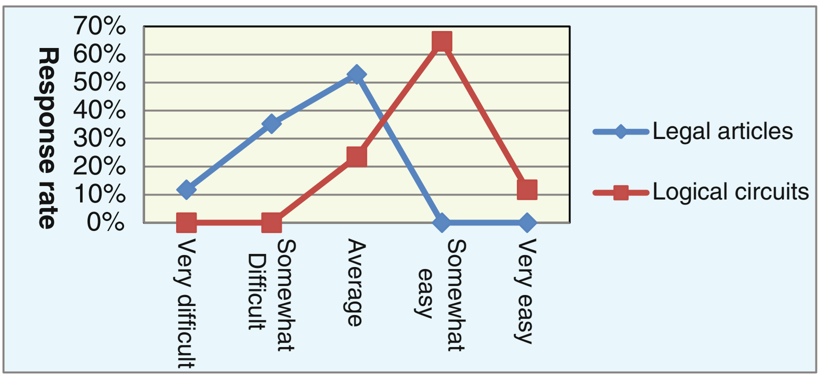

Fig. 9. Clauses versus logical circuits

property law to compare logical expressions (logical circuits) against a collection of legal texts in terms of which were easier to understand, we obtained the results in Fig. 9. From this, it is clear that, for engineering students (who tend to be good at logical thinking), the methodology of representing legal statements using logical expressions and logical circuits is easier to understand than simply reading legal articles. Thus, we can expect that a learning support system that uses this kind of logical structure to be very effective for enhancing students' understanding.

4 Discussion

In this paper, we have considered the effectiveness of a learning support system that uses a problem-solving process model to model the way that engineering students solve problems in the process of learning intellectual property law. The result was that describing intellectual property law using logical expressions is easy for engineering students to understand, and so the next step required is to continue to develop the learning support system by increasing the number predicate expressions.

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References

1. Iguchi, Y., Sera, K., Matsuoka, M.,Muramatsu, H.,Kagohara, H., et al.: Present status and future trends of intellectual property education. Patent, vol. 64, no. 14, pp. 8–18 (2011). (in Japanese)
2. Akakura, T., Ishii, T.: Development and evaluation of a self-learning support system for patent act suited to the current state of intellectual property education in engineering departments. In: Proceedings of 2016 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE 2016), pp. 128–133 (2016)
3. Akakura, T., Ishii, T., Kato, K.: The current state of intellectual property education in engineering departments of universities and development of learning support system. IEICE Technical report, vol. 116, no. 351, pp. 55–60 (2016). (in Japanese)
4. Akakura, T., Ishii, T., Kato, K.: Proposal of a problem-solving process model for learning intellectual property law using forst-order predicate logic and development of a model-based learning support system. In: 11th Annual International Technology, Education and Development Conference(INTED 2017)(2017)
5. Akakura, T., Eshita, K., Tomoto, T.: A computation-process model and system for the study of intellectual property law. IEICE Technical report, vol. 115, no. 50, pp. 21–26 (2015). (in Japanese)
6. Akakura, T., Tomoto, T.: Change in motivation of engineering students to learn about intellectual property law. IEICE Technical report, Education Technology, vol. 114, no. 121, pp. 27–32 (2014). (in Japanese)

7. Hirashima, T., Azuma, S., Kashihara, A., Toyoda, J.: A formulation of auxiliary problems. J. Japan. Soc. Artif. Intell. **10**(3), 413–420 (1995). (in Japanese)
8. Nobuoka, S., Nakamura, M., Shimazu, A.: Translating legal sentences into logical forms. In: Proceedings of the 13th Annual Meeting of the Association for Natural Language Processing, pp. 254–257 (2007). (in Japanese)
9. Tanaka, K., Kawazoe, I., Narita, H.: Standard structure of legal provisions. IPSJ SIG Technical reports, vol. 93, no. 79, pp. 79–86 (1993)
10. Kawazoe, I., Maki, T., Tanaka, K.: Standard structure of legal provisions (2) legal knowledge processing by standard structure. IPSJ SIG Notes **95**(52), 97–104 (1995). (in Japanese)
11. Shimazu, A.: Language analysis of legal documents: research on legal engineering. IEICE Technical report, vol. 110, no. 245, pp. 1–6 (2010). (in Japanese)