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Considering future directions for the specialized evaluation of educational programs for science teachers

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Abstract: Science teachers are required to demonstrate and teach scientific methods and experimental skills to students in the classroom, laboratory, and other educational settings. The use of hands-on in science teaching represents an overlap with the skill set of engineers. Although evaluation of university-level educational programs in general teaching (i.e., degree programs that qualify graduates to teach in schools) has been discussed previously, training programs for science teachers—whose required skills resemble those of engineers in some respects, and differ from those of teachers in other fields—need to be considered specifically. This paper discusses criteria for evaluating educational programs for science teachers, based on the learning achievements and professional competencies that should ideally characterize graduate science teachers.

Keywords: Science Teacher Education, Similarity to Engineer, Evaluation of Faculty of Education

1. Introduction

On August 28, 2012, the reply "Synthetic improvement policy of a teacher's nature capability which led the whole teaching profession life" of Japan's Central Council for Education was issued. This policy proposed reforming teacher training by raising teachers' basic qualification level to a master's degree, thus clearly positioning teachers as advanced professionals [1]. Moreover, it proposed to establish three new categories of teaching licenses with the following tentative names: a "basic license" for bachelor's degree graduates, a "general license" for master's degree graduates, and a "special license" not necessarily connected to a master's degree. Cooperation with teaching profession graduate school (professional degree course) and the conventional pedagogy graduate school were also proposed [1]. If the knowledge and skills of teachers are to be expanded, a higher level of training is required. What is positioning science teachers in such a situation and how is the quality of science teacher education ensured?

According to the research, the fact that science teachers teach practical skills differentiates them from most other teachers. This paper considers the future directions and quality evaluation criteria of teacher training courses in science, as a specialized field of study, paying attention to the similarities between the skills required for teaching science and for engineering. This skills overlap suggests the possibility of adapting the existing criteria for accreditation of educational programs in engineering to the case of specialist teaching programs, such as a higher degree in science teaching as a specialist profession.

2. Characteristics of Science Teachers

2.1. Teachers of Hands-on Systems and Bookwork-Based Systems

Teachers can be classified into those who teach practical skills as well as imparting a body of knowledge ("hands-on system" teachers) and those who primarily impart knowledge ("bookwork-based system" teachers). Subjects such as fine arts and music, physical education, technology and homemaking, and science are usually classified as hands-on systems (Table 1), because they involve practical skills as well as knowledge about the subject. This paper focuses on the classification of science teachers as "hands-on system" teachers and its implications for evaluating science teacher training programs.

In this paper, a science teacher is defined as a teacher of natural phenomena. A science teacher not only lectures in a classroom but also allows students to observe and experience natural phenomena. Technology allows students to be shown physical examples of the materials and devices under study, so that they can observe and investigate natural phenomena directly and analyze the results of experiments. Although certain restrictions prevent science teachers from conducting some experiments (e.g., for safety, legal, or cost reasons), most science teachers need to be well versed in various practical skills in order to prepare experimental instruments and chemicals and ensure students use safe practices during experiments. Therefore, the ideal situation is probably that a science teacher should teach practical skills in experiments about natural phenomena.

Table 1. *Classification of hands-on and bookwork-based system teachers*

Hands-on system teachers	Science teachers
	Art teachers
	Physical education teachers
	Technology & homemaking teachers
Bookwork-based system teachers	English language teachers
	Japanese language teachers
	Mathematics teachers
	Social studies teachers

2.2. Classification of Science Teachers According to Educational Facility

Science teachers can work at elementary schools, junior high schools, high schools, technical colleges, junior colleges, universities, or graduate schools, in accordance with their level of qualification. This classification system may be extended to other organizations, such as educational establishments outside the jurisdiction of the Ministry of Education, Culture, Sports, Science and Technology, vocational schools, and early childhood education. A formal science teacher classification exists for every type of educational facility (Table 2).

The skills and knowledge required of science teachers vary depending on the educational facility. At elementary school, science is taught using both hands-on and bookwork-based systems, but the level of science training received by teachers is relatively low, because science accounts for only a small part of the general curriculum. On the other hand, teachers working at junior high schools and higher-level facilities may specialize exclusively in science subjects.

Although science teachers in technical colleges, junior colleges, universities, graduate schools, and other organizations play an important role in higher education, especially in developing students' practical skills, they receive no special training to do so. If enforced, the specialized education in graduate schools will teach practical skills.

Therefore, I discuss the teacher training courses (e.g., bachelor's and master's degrees in education) through which school-level science teachers become qualified, and consider the need for the professional evaluation and accreditation of training courses in science teaching as a specialist profession. As an example of third-party course accreditation in another field, I examine the accreditation program used by the Japan Accreditation Board for Engineering Education (JABEE) to authorize engineering education programs, as engineering is already considered a specialist field of study and has many similarities with science teaching. JABEE's accreditation approach thus suggests a model for establishing science teaching as a similarly elite profession, demanding similarly rigorous standards in the professional education leading to a degree qualification.

Table 2*. Classification of science teachers by educational facility*

Educational facility	Abbreviation of role
Elementary school	E-ST*
Junior high school	J-ST
High school	H-ST
Technical college	TC-ST
Junior college	JC-ST
University (undergraduate and graduate)	U-ST
Other	O-ST

* ST: Science teacher

3. Course Evaluation in a Specialist Field of Study: Implications for Science Teacher Education

The proposal entitled "turns to construction of college program education" [2] gives the following directives for addressing the challenges of creating a third-party evaluation system for education programs.

"In reexamining a third-party evaluation system, the way field-specific evaluation is advanced becomes an important issue. The evolution of evaluation according to the needs of the field, and the range that is sought, are important in advancing the evaluation framework to ensure the quality required by the field. In such cases, aiming to provide a third-party evaluation system is problematic. The criticism of 'evaluation exhaustion' is also required to determine how evaluation may be efficiently and effectively structured according to both the organization and the field, and to advance its steady implementation from the second term of 2011". Moreover, the proposal states that "while the globalization of higher education progresses, attention must be paid to the international trend of ensuring quality".

This can be summarized as consideration of the relation of having realized it as the evaluation according to field, which suggests the need for a framework of field-specific course quality assurance, with course evaluation procedures tailored to specific organizations and compatible with international trends in quality assurance in higher education.

3.1. Program Quality Assurance Tailored to a Specialist Field of Study, and Science Teacher Education

First, to advance a framework for quality assurance in the field of science teaching, it is necessary to clarify the skills required of a science teacher, what kind of science teacher to promote, and to build the curriculum so that such teachers are produced.

Table 3. *Reference indicators for learning outcomes common to college programs*

<u>General-purpose skills</u>
Skills required for intellectual activities and occupations, or for social life.
(1) Communication skills:
Can read, write, listen, and speak in Japanese and a specific foreign language.
(2) Quantitative skills:
Can utilize symbols when analyzing, understanding, and describing natural and social phenomena.
(3) Information literacy:
Can collect and analyze various sources of information to make accurate decisions using information and communication technology (ICT), and can utilize effectively to conform to morals.
(4) Logical thinking ability:
Information and knowledge are analyzed logically from various points of view and are coherently expressed.
(5) Problem-solving ability:
A problem is discovered; information required for a solution is collected, analyzed, and sorted; and the problem is solved.
<u>Attitude and intentionality</u>
(1) Self-control:
Controls emotion and behavior.
(2) Teamwork, leadership:
Cooperates and collaborates with team members and provides leadership to others.
Moreover, directs other to set and achieve goals.
(3) Sense of ethics:
Acts according to conscience, social norms, or rules.
(4) Social responsibility as a citizen:
Displays conscientiousness as a member of society. Exercises duties and rights.
(5) Lifelong learning ability:
Displays skills for lifelong autonomy and independence. Learns new skills.

The required personal attributes will be identified, and then a curriculum will be designed to facilitate their development, and evaluation criteria will be designed to reflect their achievement. During this stage, it will be necessary to specify clearly both the desired attributes and the level to which they should be attained by candidates before receiving accreditation. For example, it should be possible to describe candidate science teachers' achievements by expressions such as "The candidate is able to -----" or "The candidate has the ability to -----". Do the Japanese faculties or departments of education guarantee the concrete achievement of graduates described above? Such a guarantee will be required to authorize a student's completion of an educational program, even though it is a report of an academic ability evaluation.

On the other hand, the Central Council for Education proposes that "reference indicators of learning outcomes required for graduation from a college program, similar to a system of minimum standards, should be cultivated in each major field" [2] under the following categories: (1) knowledge and understanding; (2) general-purpose skills; (3) attitude and intentionality; and (4) synthetic study experience and creative thinking capability. Of these, example reference indicators of learning outcomes for general-purpose skills and for attitude and intentionality are expressed clearly (Table 3).

Although Table 3 lists achievements that should be common to all graduates, the particular attainments required for specialist fields of study will differ. The business administration field was recently announced as the reference standard among specialist fields of study [3]. The document refers to "the characteristics peculiar to business administration" and "the fundamental knowledge that all the students who study business administration must achieve." An inside educational council [4] commented on "the reference standard of curriculum organization according to field", noting that "the deliberations of the Science Council of Japan are now extending to fields such as language and literature, business administration, and law, and have become instrumental in providing a model for the formulation of clear indicators of the acquisition of knowledge and development of abilities required in each specialist field of study."

The reference standard of business administration should also be applied to courses in pedagogy (and to science teaching and science pedagogy), to indicate "the characteristics peculiar to pedagogy" and "the fundamental knowledge that all the students who study pedagogy must achieve."

However, the creation of reference standards in the teacher training system has been delayed [5]. This is because the state qualification that linked the core curriculum with decision or a curriculum is directly comparable in each field of the Ministry of Education, Culture, Sports, Science and Technology's teacher-training course relations, veterinary medicine relations, and health-related exists [5]. Although the creation of reference standards for the teacher training system was shelved, the Ministry of Education is required to guarantee the quality of science teacher education (as well as other teacher education programs). However, the core curriculum studied for a teaching qualification has never guaranteed the quality of subject-specific content, such as chemistry, physics, biology, earth sciences, etc. I would therefore like to give an example of possible evaluation standards for science teacher education programs.

Regardless of whether the topic is "science education" or "science instruction study", determining the optimal "pedagogy" in the field poses a problem. This is because, as previously stated, there are great differences in the professional competencies required to teach hands-on systems versus bookwork-based systems. Further, because the types of practical skills differ across specialist fields of study, the required practical and teaching abilities also differ across fields. For example, art, physical education, science, and technology and homemaking courses are classified as hands-on systems, but the abilities required of teachers in these fields differ drastically—though teachers of science and technology and homemaking also have practical skills in common.

3.2. Relation of Evaluation According to Specialist field of Study Classified by Organization

Next, the relation of the evaluation according to specialist field of study classified by organization is described. The accreditation classified by organization seldom asks about the details of the curriculum that relate specifically to the subject of study, the target knowledge, or the level of achievement that should be attained for each subject of study. However, these points are important in course evaluations within a specialist field. It is therefore probable that evaluations tailored to specialist fields of study would be relevant when assessing individual subjects of study within an education program and would assist in efficiently evaluating graduate characteristics specific to each specialty, while still enabling the bundling of subjects at a university or faculty level for overall teacher accreditation.

3.3. International Trends

The international trends in quality assurance should also be considered. In Europe, for example, trials in higher education are advanced in accordance with the "Bologna Declaration" [6] adopted in Bologna, Italy, in 1999, which stipulates the interchangeability among European programs, an accumulation system, mutual recognition of the university unit of the country which joins is carried out.

The "Campus Asia" core base formation support [7] is offered in Japan, China, and South Korea, and is "an enterprise that carries out an exchange program that performs systematically mutual authorization of a unit, results management, and degree conferment." However, in East Asia, which currently includes Japan, educational programs are not mutually recognized over all learning domains.

In Japan, the educational program for the university graduate level of engineering and engineering work (engineer education) is accredited by JABEE. The mutual recognition of programs among the various national accreditation bodies in Asia and Europe and in the United States and Australia (14 nations) is laid out in the Washington Accord. It has been admitted that being recognized by JABEE amounts to attaining a badge of college program excellence in the international arena. This is a big flow as an international trend. This trend toward the mutual recognition of educational programs and the compatibility of study units internationally should be spread through other fields of education, including science teacher education.

4. Science Teachers as Engineers

JABEE evaluates programs for engineer education at university graduate level. Although the specific structure of each field should determine the content and quality level of the program attributes that must be guaranteed before the program is accredited, the JABEE model may have relevance as a framework for accrediting educational programs in teaching. This is because the knowledge bases and skills of teachers and engineers can be classified according to similar schemes (Table 4).

Although there are similarities in the personal attributes of volition, passion, and ethical conduct required of science teachers and engineers, they use different technical skills.

Teachers use two skills [8]: "the technical skill of a specialist subject" and "the technical skill of teaching". In the case of science teachers, each of these entails a set of practical skills. They include the handling and operation of instruments, and competence in scientific methods of analysis. Science teachers resemble engineers in the use of this form of technology and practical skills.

The second technical skill—the technical skill of teaching—is applied in the engineering context in the form of on-the-job training, through which younger generations of engineers receive technical guidance in industries such as manufacturing [9]. Probably, their technical knowledge and technology of hardly studying the technical skill to teach by high education, and using at work will be main.

As mentioned above, there are similarities between engineers and science teachers in the use of technical skills. Although it is about teachers at large, a business scholar, Drucker [10] has indicated that teachers are people with the advanced education and knowledge of a "knowledge worker" as well as chemical engineers. He mentions that "knowledge technologists" are new type of knowledge workers, and predicts an increase in the number of knowledge technologists in computers, manufacturing, and education [11]. Furthermore, the knowledge technologist, "These people are as much manual workers as they are knowledge worker; in fact, they usually spend far more time working with their hands than with their brains. But their manual work is based on a substantial amount of theoretical knowledge that can be acquired only through formal education, not through an apprenticeship" [12].

Table 4. *Similarities and differences in knowledge and skills between engineers and science teachers*

Knowledge and skills	Engineers	Science teachers
Knowledge of engineering/subject	+	+
Knowledge of education	±	+
Engineering/subject skills	+	+
Education skills	±	+

The relation with the teacher who is the educational technologist and the knowledge worker from the former who are profession people above is ambiguous, although we may perhaps draw an analogy with the classification of engineers into regular engineers, technologists, and three classes of technician [13]. An educational technologist could be defined as a person who teaches a college program at graduate level, or a technical support person. The conventional master's course completion could be classified the advanced professionals. This interpretation is in agreement with the description in the Central Council for Education's proposal [1] to "change teacher training to master's level and clearly position teachers as advanced professionals."

The research that defined the teacher's role is by Darling-Hammond [14] and Cranton [15]. It seems that the characterization of the science teacher as an engineer is similar to Darling-Hammond's portrayal of craftsmen and professionals (specialists).

Moreover, a teacher is broadly characterized from the point of ability, and the research evaluated from a point of instructional ability [16], character [17], attitudes and beliefs [18] is also made. Instructional ability consists of teaching ability, student instruction ability, executive skills, and cooperation with related professionals [19]. It appears that both the teaching skill shown by this research and specific scientific knowledge and skill are important elements of teachers' overall ability. After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

5. JABEE and Science Teacher Education

5.1. Teachers of Hands-on Systems and Bookwork-Based Systems

The educational program authorization standard of JABEE is shown below [20] (Table 5). In addition, it is important for any third-party accreditation mechanism to include a review cycle for the educational program to enable continuous improvement. Moreover, there are field-specific requirements.

Table 5. *JABEE criteria for educational programs in engineering*

Criterion 1	Learning Outcomes (Plan)
Criterion 2	Educational Methods (Do)
	2.1 Curriculum Design
	2.2 Implementation of Learning & Education
	2.3 Faculty
	2.4 Process of Admission
	2.5 Educational Environment and Student Support
Criterion 3	Achievement of Learning Outcomes (Check)
Criterion 4	Educational Improvement (Act)
	4.1Self-review of Education
	4.2 Continuous Improvement

To show that quality reviews and continuous improvements are implemented, it is necessary to document the evaluations, their findings, and the improvements that are implemented as a result, for example. The PDCA (plan, do, check, and act) cycle can be used as a tool to make such improvements.

Could science teacher education programs potentially be considered a specialist form of "engineering education", and therefore within the ambit of JABEE's accreditation framework? JABEE [21] defines its target candidates as "programs managed by the educational facilities which perform bachelor's level education, such as the four-year college of our country (including total four-year programs composed of a two-year advanced course and an engineering technical college, or a two-year advanced course and a two-year junior college program). If a program provides an engineer's basic education, the bachelor's level education currently installed is not asked".

Accepting science teacher education as engineering education poses a problem here. JABEE judge study session in 2012 in the homepage of JABEE defines an engineer on their web site as follows [22]:

"The term 'engineer' refers to a professional person engaged in technical tasks and activities. These technical tasks make full use of the core engineering knowledge base, such as mathematical science, natural science, and artificial science, and the engineer utilizes resources and the forces of nature economically, foreseeing their influence on society or the environment. Research and development, manufacturing, employment, and maintenance of hardware and software are carried out to contribute to human beings' profits and safety. While providing special service with a profession here about the specific business which society needs based on advanced knowledge and experience in actual business, which is contained in the target engineer whose mere occupation it is an occupation equipped with the autonomic function based on an original code of ethics, and is distinguished also for the researcher."

The argument is over whether a science teacher fits within this definition of engineers, which I now address.

5.2. Comparison of Tasks and Competencies between Engineers and Science Teachers

Table 6 shows a comparison of the tasks performed and competencies required by an example engineer (a chemical engineering technician) and an example science teacher who teaches chemistry.

Table 6. *Comparison of tasks and competencies between an engineer and a science teacher*

Engineer's feature which JABEE shows	**Example tasks**	
	Engineer (chemical engineer)	**Science teacher**
Fully using knowledge, such as mathematical science, natural science, and artificial science	The person calculates the rate of a chemical reaction in a chemical plant, and fully predicts the pressure change corresponding to the reaction, using calculation software.	When preparing a demonstration of hydrogen generation using the reaction of metallic sodium and water, the person selects suitable quantities of sodium and water using knowledge of chemistry and the reaction rate.
Economically utilizing resources and the forces of nature; foreseeing the influence on society or the environment.	The person knows the influence of byproducts generated by chemical reactions in the plant on society and the environment, and proposes suitable practical methods for waste containment and removal.	The person knows the risks of experimental waste fluids for students, society, and the environment, and chooses suitable management and removal methods. The person plans educationally effective small-scale experiments where possible.
Researching and developing, manufacturing, employing, and maintaining the hardware and software for artificial materials and systems that contribute to the profits and safety of humans.	The person develops an economical method for generating reaction products using catalysts without toxicity, and clarifies the optimal value of various parameters, using calculation software to strive for improvement in manufacturing efficiency.	The person creates new, impressive chemistry teaching materials to aid students' understanding, and utilizes them in lessons. The person performs various works of the method of lesson deployment, selects effective methods, and publishes the results for the benefit of other educational professionals.

For every key professional competency that JABEE ascribes to engineers (e.g., general traits such as the mastery of domain-specific knowledge like mathematics), it also attaches a practical task that illustrates this trait at work (e.g., the use of mathematics to model reaction rates in a chemical plant), thus indicating that the ability to apply knowledge and skills practically is itself a crucial feature of engineers.

Similar trait–task pairs can be devised for science teachers, as shown in the table. Both engineers and science teachers require knowledge of mathematics and science: the teacher's planning and performing of a chemical reaction requires knowledge of natural science, and the engineer's use of calculation software to calculate a reaction rate indicates knowledge of artificial science. There is a scene where a science teacher also calculates a reaction rate using calculation software. Both professionals consider the potential influence of their work on society and the environment, and both utilize resources and manage the forces of nature economically to process waste fluid. For instance, the science teacher tries to use small-scale experiments as much as possible to minimize the environmental impact of waste.

An engineer's everyday tasks were summarized above as the research and development, manufacturing, employment, and maintenance of hardware and software to contribute to human beings' profits and safety; i.e., to contribute to society. Other means of contributing to society are the development of teaching materials (soft in it being hard), their application in the classroom, and the specific teaching methods (soft) used by the science teacher.

Thus, there are many instances where the competencies and tasks of a science teacher can be related to JABEE's definition of an engineer. Though we illustrated this principle with the example of chemistry teachers, this also applies to science teachers who specialize in other areas.

However, in addition to the subject-specific technology mentioned above, a science teacher also uses the skill of teaching the specialty. This is not included in JABEE's definition of the tasks of engineers. The science teacher has to teach and lead students well and the ability to motivate attachment to science must be excellent. The skill of teaching is common to teachers in general.

On the other hand, there are many kinds of engineers, and some may have special skills that differ from those of the chemical engineer discussed here. The conformity to each item of the feature of the engineer who shows in a table differs little by little. Probably, it will be clear that dignity attachments by each item differ in the engineer treating the manufacturing industry and the software. Therefore, field-specific requirements are already accepted in JABEE's authorization standards for engineer education programs; the case of the special skills of science teachers may thus have a precedent in this framework by analogy to the special skills of different engineering sub disciplines, such as civil, chemical, software, mechanical, and electronic engineering.

Dignity attachment and directivity of an educational target to which importance is attached for especially every technical field differ from each other, and the target peculiar to the field is set up. Science teacher education programs may be considered candidates for JABEE accreditation if the technology of teaching is considered an additional field-specific skill requirement.

However, it is yet to be determined whether the acquisition of skills common to all teachers, rather than just science teachers, is a requirement in this field. That is, in science teacher education, there is a viewpoint whether thinking engineer education as important or thinking teacher education as important.

5.3. Evaluation of the Science Teacher Education in Which Education and a Specialty Carried out Technical Relation

To create standard criteria for the evaluation of science teacher education programs, a clear definition of the ideal science teacher is required. Knowledge of both teaching and the subject matter is needed, and this should be incorporated into the training material for science teachers; however, a science teacher also requires that the technical acquisition and it about a specialty should be utilizable in addition to this. Moreover, as previously noted, a teacher must have instruction abilities [16] and be of good character [17]. Teaching ability comprises instruction [18], student instruction, executive skills, and the ability to cooperate with colleagues. The content and the method of the teaching distinguish science teachers from others.

Table 7. *An example of evaluation criteria for science teacher education*

Outcome	Evaluation criteria
1. Knowledge of science	(1) Knowledge of physics
	(2) Knowledge of chemistry
	(3) Knowledge of biology
	(4) Knowledge of earth sciences
	(5) Knowledge of boundary regions
	(6) Knowledge of relationships with society, life, and engineering
2. Science skills	(1) Ability to perform physics experiments
	(2) Ability to perform chemistry experiments
	(3) Ability to perform biology experiments
	(4) Ability to perform earth sciences experiments
	(5) Ability to perform experiments of boundary regions
	(6) Ability to conduct mathematical analysis
3. Ability to design lessons	(1) Ability to design suitable lesson targets
	(2) Ability to choose suitable course content
	(3) Ability to integrate suitable course content into lessons
	(4) Ability to design suitable practice questions
	(5) Ability to design suitable evaluation criteria
	(6) Ability to set up experiments to suit students' competencies
	(7) Ability to set up safe experiments
	(8) Ability to set up experiments considering the environment
	(9) Ability to set up educationally effective experiments
	(10) Ability to set up experiments subject to constraints

Outcome	Evaluation criteria
4. Ability to deliver lessons	(1) Ability to structure the content of lessons properly (2) Ability to adapt lessons for different classes (3) Ability to ask suitable questions (4) Ability to prepare suitable experiments (5) Ability to explain the use of reagents and equipment properly (6) Ability to perform experiments safely (7) Ability to respond to success and failure in experiments (8) Ability to summarize and consider experimental results properly (9) Ability to guide suitable cleaning-up procedures after experiments (10) Ability to guide students in writing suitable experiment reports
5. Ability to evaluate lessons and learning outcomes	(1) Ability to accurately evaluate own lessons (2) Ability to accurately evaluate students' learning outcomes (3) Ability to accurately evaluate lessons performed by other teachers (4) Ability to accurately record the results of student experiments (5) Ability to evaluate lessons using quantitative methods
6. Ability to improve lessons	(1) Ability to improve lessons using past evaluations (2) Ability to improve experiments using past experimental records

I would like to analyze the instruction abilities required by science teachers from a skill perspective, and to propose relevant evaluation criteria (Table 7).

I first classify the skills required for effective science teaching. These comprise: domain knowledge, e.g., one or more specific scientific knowledge bases (chemistry, biology, etc.) including science subject matter knowledge [23]; skills in the scientific method, e.g., the ability to perform experiments; lesson design skills; lesson delivery and class leadership skills; the ability to evaluate one's own and other teachers' lessons; and the ability to apply these evaluations to improve future lessons. The last four items are intended to reflect the PDCA cycle and to produce "the science teacher who can design and improve a lesson" using former knowledge and technology. This corresponds to the "ideal science teacher" described previously. In science teacher education, it is necessary to have a curriculum describing the performance goals to be attained (the content of the evaluation criteria) and the degree of achievement required for each goal. The evaluation of a field-specific educational program should then be based on determining whether the degree-conferring institution can guarantee that all graduates attain the mandatory degree of achievement for every evaluation criterion. Table 7 suggests evaluation criteria appropriate to science teacher education.

Further, one must consider how the assessment criteria should differ between bachelor's and master's level teaching degrees. I propose two alternative methods for clarifying the differences between the learning outcomes for bachelor's and master's degree programs in science teacher education—although further argument is required about the level a graduate of each program should achieve for each outcome listed in Table 7.

6. The Need for an Evaluation System for Educational Programs in Science Teaching as a Specialist Field

Currently, there are no evaluation systems specific to individual fields of teacher education, although evaluations of teacher education are made by accreditation organizations and educational institutions, and through facility's self-evaluation. However, a specific evaluation system may become indispensable in future science teacher education that it is correctly estimated by the public organization objective and maintains a standard, though the curriculum of the outstanding science teacher education is made.

Although the big unit of a special faculty will probably also be the evaluation according to special field of study possible, even if not so, there may also be evaluation in the unit of a department. JABEE performs third-party course evaluations for specialist fields of study within engineering. Because it accredits educational programs that fall within this clear target group, it may also already have authorization in a subject of study unit.

If so, it would be appropriate to consider the faculty of the specialty of teacher education and the department with an actual subject of study. From a science teacher education perspective, the differences in teachers' abilities and in their qualifications to teach various subjects at various levels of study, such as science and technology, are factors that can be considered in teacher education for other hands-on system subjects—and for bookwork-based systems. However, when the composition teacher of the classroom to constitute is a small number of people, the workload for everyone will increase substantially during a periodical examination.

In such cases, it will be whether education is divided into a hands-on system and a bookwork-based system, and examination is undergone, or to undergo examination by the common item of the education in a bachelor's level. In the case of the latter, whether the specialty nature of each department is made to reflect how far or moderate how far poses a problem.

This research has explored the evaluation of the specialty of science teacher education. It has also considered science teacher education in view of the framework used for the authorization of specialist engineering programs by JABEE. When the time comes to implement an evaluation system tailored to science education as a specialized field, and if Japanese education policy-makers form the view that science teachers' skills and tasks overlap significantly with those of engineers, the PDCA cycle used by JABEE will be one important reference.

Furthermore, I believe that a system that offers quality assurance appropriate to specialist fields of study should be built, adding the consideration about the international standard of the engineer education of science teacher education, a difference, peculiarity, and science teacher education in addition. I also support the immediate introduction of an accreditation framework for master's level courses in science teaching specifically.

7. Conclusion

Teacher education includes hands-on and bookwork-based system education. It has been shown that the former is applied to science teacher education. Moreover, engineering education is considered more closely related to science teacher education than to other fields of teacher education. The features that science teacher education has in common with engineering education could be included in the field and may bring science teacher education programs within the ambit of the evaluation system of the Japan Accreditation Board for Engineering Education (JABEE). However, the uniqueness of science teacher education must also be considered, because there are differences between science teachers and industrial engineers. Furthermore, any science teacher education of an international standard should be considered as well as master's level courses.

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