# Towards the Identification of ESD Competencies Required for Pre-service Science Teachers

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**Abstract** The purpose of this study was threefold. First, a thorough review of models related to ESD competencies was completed. Second, the study developed and conducted a prospective science teachers' course ("Elementary Science Education Methodology Development") that targets Education for Sustainable Development (ESD) based on Lesson Study methodology. And third, the study evaluated the course's merits and values based on the process of students' understanding of science lessons. Stufflebeam's (2003) Context, Input, Process, and Product (CIPP) evaluation model guided the development and assessment of this two-month course for third-year undergraduate students in the university's science education department. When conducting a trial of the course, diverse evidence was acquired that suggests it promoted students' understanding of and a capacity to accomplish, what science teachers should do in order to teach science lessons incorporating ESD. Consequently, this trial empirically identified essential competencies that are found as key components to the domains "Facilitate Learning" and "Continue to Learn and Create" located in the study's draft version of an Asia-Pacific ESD Teacher Competency Framework.

## 1 Introduction

ESD occupies a prominent place on the United Nation's 2030 Agenda for Sustainable Development and for the Sustainable Development Goals (SDGs) adopted in 2015. ESD is a key enabler to achieving all the SDGs, according to the UN General Assembly's resolution 72/222. Teachers play the most important role in this global pursuit of ESD. For example, in the UNESCO's ESD promotion framework "Global Action Programme on ESD" (for the period 2015–2019) and the subsequent "ESD for 2030" (for the period 2020–2030), the spread and development of ESD teacher education is taken up as a priority action area.

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Recognizing the critical importance of teachers in the context of the SDGs, Okayama University has tackled teacher education on ESD by advancing pre-service teachers' training programs at the undergraduate and graduate levels, as well as advancing the in-service teachers' training programs in cooperation with various boards of education (Yutani & Fujii, 2014). Okayama University holds the only UNESCO Chair on ESD in Asia, and it participates in the Okayama Regional Centre of Expertise on ESD, a center authorized by the United Nations University in Shibuya, Tokyo.

Our pre-service science teacher programs were enhanced by incorporating such content as follows: (a) the ideas and purposes of ESD, (b) the linkage between science education and ESD, and (c) examples of science lessons on ESD. These are now taught in two compulsory courses, "Elementary Science Education Methodology" and "Secondary Science Education Methodology." For example, in the linkage between science education and ESD topics, we introduced how to connect science education and ESD by considering the purposes, content, and activities of science either as a subject, or individually, or as a learning system. Through these program developments, we discovered that science teacher education on ESD should be based on Lesson Study[1] and it should also be linked to teachers' professional knowledge of education and scientific literacy with respect to the major themes in ESD, such as climate change/energy problems, biodiversity, prevention of natural disasters, and sustainable consumption and production.

Presently, we have been developing two new elementary and secondary pre-service training programs on ESD. The first program serves pre-service students. It offers a special emphasis on Lesson Study during a compulsory two-month course. Students choose either "Elementary Science Education Methodology Development" or "Secondary Science Education Methodology Development." In both courses, third-year undergraduate students enroll and participate directly following their one-month school practice. In these two courses (the focus of this chapter), undergraduate students conduct a Lesson Study such as creating a lesson plan, practicing a sequence of demonstration lessons, and reflecting on the lessons that are practiced. Such rigorous engagement leads students in learning science education methodology in a practical way. Also, students are required to incorporate the ideas and purposes of ESD into units and topics of science lessons in such a way that motivates themselves to practice and complete the lessons.

In the second program, we focus on an elective course offered at both the undergraduate and graduate levels, "Science Education and ESD," which aims to train talented science teachers. The course helps them learn about the development and utilization of bioenergy. The students registered in this course: (a) attend a lecture which addresses junior and senior high school chemistry lessons focused on sustainability (Fujii & Ogawa, 2016), and (b) visit sites where bioenergy based on woody biomass is developed and utilized. Also, they are required to describe how to incorporate ESD ideas and purposes into the topics of science lessons.

[1] A rigorous sequential process for developing a lesson plan collaboratively with colleagues.

As mentioned just above, the *pre-service* science training program's development, trial, and evaluation are examined further in this chapter. What sort of competencies are required by ESD science teachers for attaining successful outcomes to their teaching?

## 2 Competencies for Sustainability and ESD

### *2.1 Competency for Sustainability*

To achieve the SDGs, UNESCO has been developing ESD to date and advocating a new idea, Education for Sustainable Development Goals (ESDGs). This describes an ideal way for education to achieve the SDGs with ESD at the core. It assumes that the SDGs constitute a big agenda, and the SDGs cannot be achieved without education. According to a report entitled "Education for Sustainable Development Goals: Learning Objectives" (UNESCO, 2017), "sustainability citizens" is the image of humanity that ESDGs propose. Sustainability citizens are those who can connect, communicate, create, and engage in a change in today's complex and uncertain society. Similarly, the Japanese school curriculum guidelines expect that sustainability students will have rich creativity to become creators of a sustainable society.

Subsequently, the UNESCO report (2017, p. 10) lists the following "key competencies for sustainability" as necessary competencies for such citizens: systems thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem-solving (see Table 1). This list of competencies is considered to be a milestone in light of the competencies discussed over the past few decades. Furthermore, these competencies overlap with "abilities that students should develop in ESD" as shown by the Japan National Commission for UNESCO: specifically, (1) values on sustainable development, for example, respect for humans, respect for diversity, non-exclusivity, equal opportunity, and respect for the environment; (2) system thinking, for example, understanding the background of problems and phenomena and multifaceted and comprehensive perspective; (3) critical thinking, for example, ability to criticize; (4) data and information analysis ability; (5) communication skills; and (6) leadership improvement. Moreover, it is noteworthy that key competencies for sustainability include those of anticipation, strategy, and self-awareness. The SDGs emphasize: to capture the complex relevance of the issues from the aspects of environment, economy, and society; to set goals and indicators, and to review the process of the realization; to set priorities and to work on for a desirable future; and to expand partnerships from the bottom up. These are new approaches of the SDGs, and the key competencies for sustainability reflect this approach.

Following key competencies for sustainability, the report lists the learning objectives in the cognitive, socio-emotional, and behavioral domains for each goal of the

**Table 1** Key competencies for sustainability

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|---|---|
| *Systems thinking competency*: the abilities to recognize and understand relationships; to analyze complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty | *Collaboration competency*: the abilities to learn from others; to understand and respect the needs, perspectives, and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem-solving |
| *Anticipatory competency*: the abilities to understand and evaluate multiple futures—possible, probable, and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes | *Critical thinking competency*: the ability to question norms, practices, and opinions; to reflect on own one's values, perceptions, and actions; and to take a position in the sustainability discourse |
| *Normative competency*: the abilities to understand and reflect on the norms and values that underlie one's actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge, and contradictions | *Self-awareness competency*: the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires |
| *Strategic competency*: the abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield | *Integrated problem-solving competency*: the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive, and equitable solution options that promote sustainable development, integrating the above-mentioned competencies |

SDGs. This composition of the domains is based on an understanding of the importance of non-cognitive skills and behavioral abilities in ESD. For example, Goal 13 is "Take urgent action to combat climate change and its impacts," the learning goals for each domain are as shown in Table 2.

The cognitive domain requires a basic knowledge and understanding of the phenomena of climate change, its artifacts and consequences, and addressing climate change (i.e., prevention, mitigation, and adaptation). Of particular note is the attempt to make learners understand the consequences of climate change from multiple perspectives: ecological, social, cultural, and economic. This understanding will require anticipatory and system thinking competencies.

The socio-emotional domain mainly requires a connection with others for climate protection, as well as the reflection on one's own values and actions. To address these requirements, it is important to correlate various competencies, such as collaboration, self-awareness, norms, critical thinking, and strategy.

The behavioral domain requires the following: to start from reviewing one's own actions, to determine what actions should be taken, and to develop individual actions

**Table 2** Learning objectives for SDG 13 "Climate Action"

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|---|
| *Cognitive learning objectives* |
| 1. The learner understands the greenhouse effect as a natural phenomenon caused by an insulating layer of greenhouse gases<br>2. The learner understands the current climate change as an anthropogenic phenomenon resulting from increased greenhouse gas emissions<br>3. The learner knows which human activities—on a global, national, local, and individual level—contribute most to climate change<br>4. The learner knows about the main ecological, social, cultural, and economic consequences of climate change locally, nationally, and globally and understands how these can themselves become catalysing, reinforcing factors for climate change<br>5. The learner knows about prevention, mitigation, and adaptation strategies at different levels (global to individual) and for different contexts and their connections with disaster response and disaster risk reduction |
| *Socio-emotional learning objectives* |
| 1. The learner is able to explain ecosystem dynamics and the environmental, social, economic, and ethical impact of climate change<br>2. The learner is able to encourage others to protect the climate<br>3. The learner is able to collaborate with others and to develop commonly agreed-upon strategies to deal with climate change<br>4. The learner is able to understand their personal impact on the world's climate, from a local to a global perspective<br>5. The learner is able to recognize that the protection of the global climate is an essential task for everyone and that we need to completely re-evaluate our worldview and everyday behaviors in light of this |
| *Behavioral learning objectives* |
| 1. The learner is able to evaluate whether their private and job activities are climate-friendly and—where not—to revise them<br>2. The learner is able to act in favor of people threatened by climate change<br>3. The learner is able to anticipate, estimate and assess the impact of personal, local, and national decisions or activities on other people and world regions<br>4. The learner is able to promote climate-protecting public policies<br>5. The learner is able to support climate-friendly economic activities |

into actions of the whole society. The behavioral domain also mentions empathy and empathetic leadership to others. In order to achieve the behavioral learning objectives, it is therefore important to make full use of competencies, such as critical thinking, self-awareness, collaboration, and strategy, as well as to exert integrated problem-solving competency.

These learning objectives will be a guideline in designing ESDGs with a focus on ESD. With reference to the guidelines, it is important to promote ESDGs in elementary and secondary schools as well as teacher education institutions.

## 2.2 Teachers' Competencies for ESD

Various models have been proposed for the competencies required of ESD teachers. Sleurs' (2008) model is one of the key examples, the result of a project of the United Nations Economic Commission for Europe (UNECE). Named "Dynamic model for ESD competences in teacher education," it incorporates ESD into the curricula of teacher education institutions. Teachers are seen not only as an instructor, but as a person in dynamic relationships with students, colleagues, and the wider society. Teachers' competencies for ESD are described at the intersection of (a) three professional dimensions: teachers as individuals, teachers at educational institutions, and teachers in society; and (b) three overall competencies: teaching, reflecting/visioning, and networking. The ESD competencies that shape the learning process for sustainable development are knowledge, system thinking, emotions, values and ethics, and action.

The "KOM-BiNE" (Competences for ESD in Teacher Education) model proposed by Rauch, Streissler, and Steiner (2008) consists of three behavioral areas for teachers: instructional setting, institutional setting, and society at large. This is similar to the professional dimensions of Sleur's (2008) model. The competency elements for ESD are in order from the center of the circle: (1) knowing & acting and valuing & feeling; (2) communicating & reflecting; and (3) visioning, planning & organizing, and networking.

Subsequently, Bertschy, Künzli, and Lehmann (2013) proposed the ESD-specific professional action competency in kindergarten and primary school, referring to UNECE's (2012) and Sleur's (2008) ESD competency models. Bertschy's model focuses on the knowledge found in complex and multifaceted topics of ESD, and on the ability to turn them into teaching/learning materials, as well as to constructively cope with conflicts associated with such topics. In addition, Bertschy's model highlights ethical judgment as an educational goal and as a central part of the co-creation competency that students should develop.

Another influential teacher competency model for ESD was derived from UNESCO Bangkok's project "Integrating Education for Sustainable Development (ESD) in Teacher Education in South-East Asia" (UNESCO, 2018). The model adopts a review tool focused on the extent to which ESD is integrated into teacher education (UNESCO, 2010). Seven teachers' competencies to be evaluated in ESD practice are shown in Table 3: ESD concept, ESD content, ESD methods, ESD curriculum mainstreaming, ESD policies, ESD and communities, and ESD institutional mainstreaming.

UNESCO (2017) described learning objectives that teachers as practitioners of ESDGs should promote (Table 4). These objectives can be grouped into three main areas. The first objective is to learn about the key issues of sustainable development and to develop multifaceted and multidisciplinary perspectives on them, which means developing a basic understanding of sustainable development and many viewpoints concerning it. The second objective is to apply the essential elements of

**Table 3** ESD competencies proposed by Southeast Asia ESD teacher educators' network

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|---|---|
| *1. ESD concept*<br>Are teachers developing an understanding of the philosophy, objectives, and characteristics of ESD? | *5. ESD policies*<br>Are teachers developing an appreciation of the relevance of ESD and an awareness of the current policies and initiatives aligning ESD to national development and education goals, specifically in terms of quality education? |
| *2. ESD content*<br>Are teachers developing their knowledge to understand and explain these local and global issues that impact on achieving sustainable development? | *6. ESD and community*<br>Are teachers developing appropriate strategies for identifying and engaging with communities and local issues in relation to global issues? |
| *3. ESD methods*<br>Are teachers developing the skills to use a variety of effective teaching and learning approaches to achieve the wide range of ESD objectives? | *7. ESD institutional mainstreaming*<br>Are teachers developing an awareness of the institutional structures and processes that are crucial for successfully integrating ESD? |
| *4. ESD curriculum mainstreaming*<br>Are teachers developing an understanding of how to implement ESD as a cross-curricular theme and how ESD can enrich subject teaching? | |

sustainable development (e.g., cultural diversity, gender equity, social justice, environmental protection, and personal development) to one's educational practices, as well as to assess and evaluate the development of learners' sustainability competencies during those practices. This constitutes facilitating ESD education practices. The third objective is to cooperate and act to spread ESD practices with others in schools and communities, both of which constitute expanding ESD engagements.

Teachers are required not only to gain competencies for sustainability citizens (e.g., knowledge, skills, attitudes, values, motivation, and commitment) but also to obtain profession-general competencies in order: (a) to help students gain those competencies as a result of innovative teaching practices and (b) to expand these practices to people around the students and teachers.

Based on these competency models, we have been promoting a project in the Asia-Pacific region that creates a competency framework for ESD teachers (Okayama University, 2019) (see Fig. 1). The model centered on shaping the future, and it consists of three domains: (a) facilitate learning, (b) continue to learn and create, and (c) connect, collaborate, and engage.

In practice, what is a profession-specific ESD competency required for science teachers? The following case study illustrates an answer.

**Table 4** Learning objectives for teachers to promote ESD

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| Know about sustainable development, the different SDGs, and the related topics and challenges |
| Understand the discourse on and the practice of ESD in the local, national, and global context |
| Develop their own integrative view of the issues and challenges of sustainable development by taking into account the social, ecological, economic, and cultural dimensions from the perspective of the principles and values of sustainable development, including that of intergenerational and global justice |
| Take disciplinary, interdisciplinary, and transdisciplinary perspectives on issues of global change and their local manifestations |
| Reflect on the concept of sustainable development, the challenges in achieving the SDGs, the importance of their own field of expertise for achieving the SDGs, and their own role in this process |
| Reflect on the relationship of formal, non-formal, and informal learning for sustainable development, and apply this knowledge in their own professional work |
| Understand how cultural diversity, gender equality, social justice, environmental protection, and personal development are integral elements of ESD and how to make them a part of educational processes |
| Practice an action-oriented transformative pedagogy that engages learners in participative, systemic, creative, and innovative thinking and acting processes in the context of local communities and learners' daily lives |
| Act as a change agent in a process of organizational learning that advance their school towards sustainable development |
| Identify local learning opportunities related to sustainable development and build cooperative relationships |
| Evaluate and assess the learners' development of cross-cutting sustainability competencies and specific sustainability-related learning outcomes |

# 3 Case Study: Prospective Science Teachers' Training Programs for ESD

## *3.1 Program Development*

For our development process, we adapted a framework informed by Stufflebeam's (2003) Context, Input, Process, and Product (CIPP) evaluation model that has been used for the evaluation of curricula and educational programs as a management-oriented evaluation tool. The CIPP evaluation model can provide the key information necessary for making a decision on how to develop curricula and educational programs. Therefore, the model provides a systematic perspective on the development, practice, and evaluation of ongoing program development (Nozawa, 2012).

The CIPP evaluation model is composed of four components: context, input, process, and product evaluation. The context evaluation is often referred to as needs

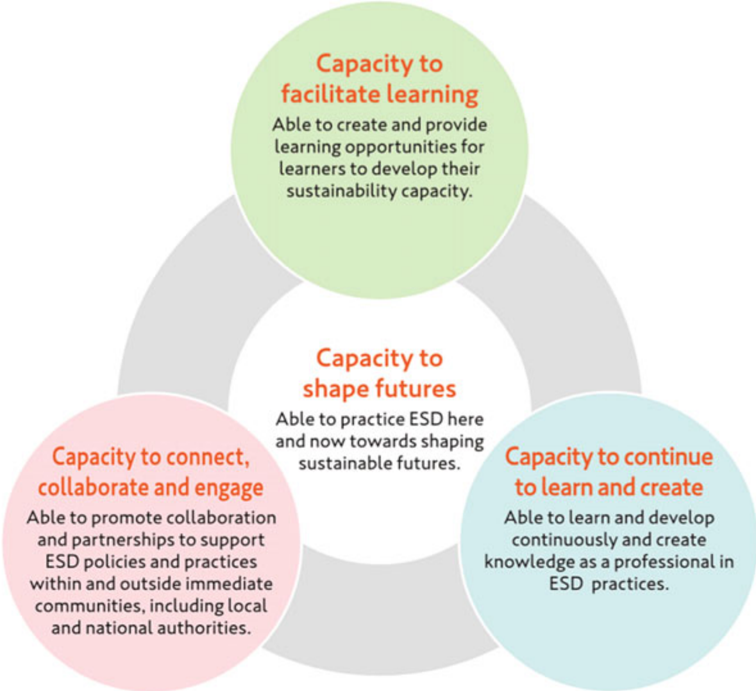


**Fig. 1** Draft of Asia-Pacific ESD teacher competency framework

assessment. It asks the question, "What needs to be done?" It helps with the assessment of problems, assets, and opportunities within a defined community and environmental context (Stufflebeam & Shinkfield, 2007). It clarifies the objectives of program development. The input evaluation requires a project to address its identified needs. It asks the question, "How should it be done?" and identifies procedural designs and educational strategies that will most likely achieve the desired results. It defines the structure and content of the program. The process evaluation monitors the project implementation process. It asks the question, "Is it being done?" and provides an ongoing check on the project's implementation process. It documents the process and provides feedback regarding (a) the extent to which the planned activities of the program are carried out and (b) whether adjustments or revisions to the plan are necessary. The product evaluation identifies and assesses project outcomes. It asks the question, "Did the project succeed?" and is similar to an outcome evaluation. It measures, interprets, and judges a program's outcomes by assessing their merit, worth, significance, and probity.

Referring to examples of program development (e.g., Zhang et al., 2011) used the CIPP evaluation model, we conducted a procedure to analyze the information obtained in each component and to carry out the development, practice, and evaluation of the program (Table 5).

**Table 5** Procedure of program development adapting the CIPP evaluation model

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| *Context evaluation* |
| We identified the needs of students for school science lessons incorporating ESD and the things that students must learn to be able to provide such science instruction; therefore, we conducted an initial qualitative assessment using a questionnaire |
| *Input evaluation* |
| We created a plan for the teacher training program corresponding to the identified needs, reviewed relevant literature, and considered the advice and expertise of individuals such as other university teachers. Also, we created a framework to evaluate the plan and confirmed whether it meets the needs that were identified |
| *Process evaluation* |
| We monitored the program process and potential procedural barriers and identified students' needs for program adjustments, that is, their current questions and difficulties related to the processes of Science Lesson Study incorporating ESD. Therefore, we observed Lesson Study activities and kept a log of activities, interviewed the students, and reviewed their self-reflections. Also, we provided advice relevant to the students |
| *Product evaluation* |
| We measured, interpreted, and judged teacher training program outcomes; therefore, we conducted an initial qualitative assessment using a questionnaire for students and reviewed the students' self-reflection through group interviews and their final reports |

## 3.2 The "Elementary Science Education Methodology Development" Course

As mentioned above, we organized a compulsory two-month course titled "Elementary Science Education Methodology Development" as part of the training program for third-year prospective science teachers. The course consisted of 32 h in total (four hours per week for eight weeks, December 6, 2016 to February 7, 2017), following the students' one-month school practice. Sixteen students registered, all belonging to the Department of Science Education, Faculty of Education, Okayama University.

Table 6 shows the learning objectives and syllabus planning of the course. Based on their school practice experience, the students conducted a Lesson Study, which included making lesson plans, practicing a sequence of demonstration lessons, and reflecting on these practiced lessons. This resulted in a practical understanding of this science education methodology. In addition, they were required to (a) incorporate their own ideas and the purposes of ESD into science lesson units and (b) pick topics they wanted to practice.

## 3.3 Context Evaluation

In order to set up the purposes of the program, we conducted the initial qualitative assessment by administering a questionnaire to 16 students (Table 7). When

**Table 6** The "Science Education Methodology Development" course

| | |
|---|---|
| *Learning objectives* | |
| The students will learn science education methodology through Lesson Study | |
| *Syllabus planning* | |
| 1st | (1) Reflection on experienced school practice and completed science education courses, and<br>(2) Attendance of a lecture on the social background of the promotion of ESD, ideas and purposes of ESD, and an exemplar of elementary science integrating ESD |
| 2nd to 4th | (1) Selection units and topics for lesson design, and then<br>(2) Development, presentation, and modification of lesson plan |
| 5th to 7th | Demonstration of a lesson and reflection of its effect |
| 8th | Presentation of learning outcomes |

**Table 7** Questionnaire used for context evaluation and product evaluation

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|---|
| Question 1 Is it necessary to conduct elementary science lessons incorporating ESD? Why do you think so? |
| Question 2 What kind of elementary science lessons incorporating ESD should be practiced? |
| Question 3 What should you learn to practically conduct the above-mentioned elementary science lessons in school? |

describing the responses to the questionnaire just below, the following two-part protocol is followed: the *number* of respondents who wrote a similar idea to the one stated is noted in brackets (x), and a *representative* response example is indicated by quotation marks (" ").

Regarding Question 1, all the students responded positively. The total number of responses to the question "Why do you think so?" was 17 (multiple responses, same for other questions). A variety of reasons were provided, which were derived from various aspects of society, especially tackling environmental problems (9) (e.g., "The environmental problems are causing a grave situation."). In addition, there were reasons based on the children's development (7) (e.g., "The pupils can think about systems of environment, energy, and so on.").

Regarding Question 2, the total number of reasons was 23. These related to aspects of the learning objectives (9) (e.g., "In the lessons, we should help pupils think about what they can do to the natural environment."). In addition, they were described in terms of learning content (9), especially natural disasters (4) (e.g., "Emphasis on natural disaster topics"), and resources/energy (3) (e.g., "We should discuss the period of years within which energy will be depleted."). Some were also described on the basis of learning methods (5) (e.g., "In the lessons … we should help pupils solve problems involving the natural environment, along with the law of nature. This is an advantage of science lessons.").

Regarding Question 3, the total number of responses was 24. The reasons described were based on aspects of research (12), especially research on materials for the lessons (7) (e.g., "I need to understand the business efforts extended in the development of energy.") and research on ESD (5) (e.g., "I should gain knowledge on the essentials of ESD through my own efforts."). In addition, the relevant descriptions were based on research concerning teaching methodology (6) (e.g., "I have to understand the results of ESD and the points in it that can be improved; I should also understand what ESD lessons are currently being carried out in schools."). On the other hand, some responses were related to the students' own behavior (4) (e.g., "I will take action with regard to energy problems and thus show these actions to pupils.").

Therefore, we believe that

(1) Many students understood the necessity for science lessons that incorporated ESD, based on the aspects of tackling environmental problems, as well as on children's development of thinking;
(2) Respondents thought that these science lessons should deal with natural disasters, energy/resources content, and enabling pupils to think how to act; and
(3) Respondents thought that by conducting these science lessons, they would gain an understanding of ESD itself through the examples in lessons and related teaching materials.

## *3.4 Input Evaluation*

Corresponding to the needs identified by the questionnaire responses, we planned our teacher training course in three phases. We referred to the relevant literature and expert advice provided by university teachers from the Department of Science Education.

*Phase 1*. In order to enhance the students' understanding of ESD, we explained the social backgrounds of the promotion of ESD and its idea of sustainability. We introduced examples of elementary science lessons that incorporated ESD (Shinkosyuppansya Keirinkan, 2015).

*Phase 2*. We supported the students' Lesson Study activities, which they utilized to enhance their understanding of the main topics in ESD, such as climate changes/renewable energy, biodiversity, and natural disasters. We also supported their understanding of why and how we incorporated ESD into science lessons; that is, we introduced them to learning objectives and to the learning contents and methods of ESD science lessons.

*Phase 3*. Finally, we created a check sheet in order to evaluate and confirm whether these plans met their needs.

**Table 8** Units and topics of elementary science lessons incorporating with ESD

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|---|---|
| Third grade | Working of wind and rubber |
| | Pupils try to stop the handmade car at a specific location through the use of energy of rubber, in order to understand the way their project conceptualizes energy |
| Fourth grade | Season and living things |
| | Pupils understand that animals and plants are changing their shape and surviving, corresponding to the four seasons |
| Fifth grade | Running water |
| | Pupils consider levees that are the strongest and eco-friendly and understand the relationship between nature and human beings |
| Sixth grade | Landscape and its change |
| | Pupils reflect on why a famous Japanese volcano, "Sakurajima," has connected to the main island and discover the greatness of nature |
| | Utilization of electricity |
| | Pupils understand the bidirectional linkage between electricity and energy converted into electricity |

## 3.5 *Process Evaluation*

Throughout the processes of the course, we helped students reflect on their school practice experience and on the science education courses they completed. Four types of events were subsequently experienced by the students:

1. They attended a lecture about the social foundation for promoting ESD, the ideas and purposes of ESD, and examples of elementary science lessons that had incorporated ESD.
2. They selected units and topics for lesson making (Table 8) and then presented and modified their lesson plans.
3. They demonstrated their lessons and reflected on their own lessons taught.
4. They presented the learning outcomes throughout the course.

During the second event described just above, we conducted the process evaluation and monitored the course's process while placing a special emphasis on the students' activities. Students often asked themselves the question, "What is ESD?" They also had many questions and difficulties regarding setting up the learning objectives and the framing of the content pupils should learn. We provided them with a minimum amount of necessary advice, but we helped them improve their own problem-solving.

## 3.6 *Product Evaluation*

We conducted the same initial qualitative assessment by administering the questionnaire (Table 7) to sixteen students in the last week of the course. Regarding Question

1, all the students responded positively again. The number of responses to the item based on the aspects of children's development was nine. Those responses focused on promoting children's cognitive development and behavior, for example,

"Because through science lessons that incorporate ESD … I think that children might change and deepen their view of nature and the environment near them as well as living things. Moreover, the children might change their behavior and their attitude towards the environment near them, so that a spot is extended to a face."

Regarding Question 2, the total number of responses was 26. The responses related to learning objectives of science lessons with ESD (6), for example,

- "Science lessons that incorporate ESD should help children acquire the competencies necessary for the future and basic ways of thinking about these competencies,"
- "I think that, considering science lessons from various aspects, we need to carry out education and lessons in order to enable our decision making," and
- "In science lessons that incorporate ESD … it is necessary to help children change their recognition from being *human being centered* to being *human being in nature*."

Furthermore, the responses based on aspects of learning content (11) were included not only in those related to the subject matter itself (e.g., energy/natural resources) but also in those related to the organization of teaching materials, for instance, "If we find a familiar natural phenomenon that is useful for ESD, we should incorporate it into science lessons as teaching material." There were also various responses regarding learning methods (9). These were placed into two categories: (a) problem solving, for example, "(For science lessons incorporating ESD) … it is very important for children themselves to inquire how to solve problems by using the basis of previous learning experiences;" and (b) lessons with realistic emotion, for example, "The lessons should provide an opportunity to help children think about how the learning content is relevant to their own lives and helps them gain real feelings."

Regarding Question 3, the total number of responses was 26. The responses about researching the subject matter of science lessons with ESD (13) were categorized on the basis of learning materials for lessons (5), learning what ESD itself means (3), learning how to incorporate ESD into teaching materials (3), and so on. An example of the last category was "The most important thing is researching the subject matter. I need to inquire about, and determine the parts of, the science lesson units into which we can incorporate aspects of ESD." Moreover, there were responses about the teaching methods (9), especially with regard to learning how to incorporate ESD into teaching methods (4) (e.g., "I need to consider what content we allow children to grasp, in terms of approaching aspects of ESD."). Furthermore, there were some responses on research concerning children (4), especially children's thinking in ESD lessons (3) (e.g., "Considering children's thinking … I have to be able to look at and think about things from various viewpoints and standpoints.")

Subsequently, we reviewed the students' self-reflections at the end of the course (verbal data) and their final written reports (descriptive data). These qualitative data were very similar to the responses to Question 3 of the questionnaire.

By conducting and assessing this two-month trial of the elementary science education methodology development course, three results showed clear evidence that the program promoted the students' understanding of science lessons incorporating ESD.

*The First Result*. The students better understood the necessity of science lessons incorporating ESD, especially in terms of children's development. Regarding the reasons for elementary science lessons incorporating ESD, the students pointed out both the promotion of children's thinking and their behavior.

*The Second Result*. Regarding "desirable practices for science lessons incorporating ESD," the students imagined various ideas for learning objectives, content, and lesson methods. For example, they pointed out that when writing learning objectives, one should place special emphasis on developing necessary skills for the future, such as making decisions and promoting a view of nature in accordance with the motto "Human beings in Mother Nature." Moreover, students mentioned that it was necessary to organize their teaching materials.

*The Third Result*. The students understood more clearly the necessity of their own learning in order to conduct science lessons with ESD. In particular, they mentioned the importance of research: the subject matter, the teaching methods, as well as the processes and expandability of children's thinking.

Thus, by understanding what ESD is, the students enhanced their understanding of what science teachers should help pupils acquire from science lessons that incorporate ESD. Put simply, the students gained an understanding of setting up appropriate learning objectives for ESD science lessons. This is an educationally significant merit of the trial course that was developed.

## 4 Findings

The changes that occurred to prospective teachers during this intervention program identified the required ESD competencies needed by science teachers. With the help of our competency framework (Fig. 1), Asia-Pacific ESD Teacher Competency Framework (Okayama University, 2019), elements of these competencies were also identified.

In the first domain, that is, the Capacity to Facilitate Learning, one essential element is the pedagogical knowledge for creating science lessons that incorporate the concept of sustainability. Science teachers are required to have competencies in *adjusting* their objectives, the content, and their methods in order for their students to build the competencies needed for their future. These competencies include rational and reasonable decision-making, taking wise actions, all with the view of *human beings in nature.* A knowledge on disciplinary, interdisciplinary, and transdisciplinary perspectives on science education is required for these adjustments to be successful. Thus, science teachers need to acquire knowledge and abilities about making lesson-specific adjustments to supplement the work of colleagues in other subjects and learning areas who have multifaceted contacts with ESD.

In the second domain, that is, the Capacity to Continue to Learn and Create, science teachers need the abilities: (a) to reflect on their accumulated knowledge, (b) to conduct science lessons incorporating the concept of sustainability, and (c) to innovate with teaching materials and various pedagogical methods. These abilities are closely linked to the motivation and volition for being a teacher who constantly learns.

Looking to the future, the third domain, that is, the Capacity to Connect, Collaborate and Engage, requires competencies that have not been identified in our intervention program. They connect with the work of Sleurs (2008) and the KOM-BiNE model of Rauch, Streissler, and Steiner (2008). These models for ESD competencies in teacher education have a dynamic relationship with students, colleagues, and a wide range of societies. ESD teachers will play a role as a transformer towards a sustainable society. To foster the competencies needed for such teachers, other intervention programs should be envisioned and designed so that prospective teachers are directly connected to the real-life setting of schools and society. It should probably be developed as a science teacher training program for ESD, with a special emphasis on open learning environment, as exemplified by Kater-Wettstädt, Bruhn, Bürgener, and Barth (2019).

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