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Promoting critical knowledge, skills and qualifications for sustainable development in Africa: How to design and implement an effective response by education and training systems

Sub-theme 1

Common core skills for lifelong learning and sustainable development in Africa

Science Education for Developing Core Skills Necessary for Scientific and Technological Development
—Experiences of Japan and Africa—

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Acronyms and abbreviations

ADEA	Association for Development of Education in Africa
ASEI	Activity, Student, Experiment and Improvisation
CEMASTEA	Centre for Mathematics, Science and Technology Education in Africa
IIEP	International Institute for Educational Planning
INSET	In-Service Education and Training
JICA	Japan International Cooperation Agency
PDSI	Plan, Do, See and Improve
SMASSE	Strengthening of Mathematics and Science in Secondary Education
SMASE	Strengthening Mathematics and Science Education
WECSA	Western, Eastern, Central and Southern African (Countries)

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1. ABSTRACT

1. As it is widely acknowledged that science education contributes to laying the foundation for scientific human resources, many African countries have endeavored to strengthen science education, in particular, by shifting the focus of education on from basic education to post-basic education. However, the experience of high-performing economies in Asia suggests that providing quality science education at the basic education level is even more important because science education at that level can effectively foster core skills such as scientific thinking skills and problem solving skills, referred to as scientific literacy for ordinary citizens.

2. The study first reviews literature on science education curriculum and the aspects of the cognitive and cultural domains of science education. It also analyses Japan's experience in science education development and lesson delivery, and projects supported by the Japan International Cooperation Agency (JICA), which are aimed to improve science and mathematics education in Africa by introducing a learner-centered teaching and learning approach called ASEI-PDSI approach.

3. Based on the literature review and the experiences of Japan, the study proposes that science education at the basic education level should be strengthened. In particular, the quality of lesson delivery at that level needs special attention. For instance, in order for science lessons to be leaner-centered, lessons should properly deals with students' pre-instructional conceptions and cultural difference between learners' life and school science.

4. In order to learn not only from theories but also from actual experience on the ground, it is important to create a forum where African countries can share experiences and good practices to bring about improvements in teaching and learning in science education in Africa.

2. EXECUTIVE SUMMARY

Introduction

5. The study discusses a kind of science education that contributes to scientific and technological development, focusing on two aspects of science education: nature of science curriculum; and effective teaching and learning methods. Based on experiences in science education development in Japan and Africa, the study proposes teaching and learning methods that can effectively foster core skills such as scientific thinking and problem solving skills.

6. Science education is considered to contribute not only to laying the foundation for human resources that are directly involved in science and technological development such as scientists, researchers, and engineers, but also to fostering core skills such as scientific thinking and problem solving skills, referred to as 'scientific literacy' for ordinary citizens to participate in the society and work places. It is thus necessary to consider when and what kind of science education should be provided to facilitate scientific and technological development.

Core Skills for Scientific and Technological Development

7. In the current world where any issues in the society depend on science to some extent, all citizens are required to have a certain level of scientific knowledge and scientific thinking skills. Scientific knowledge and skills required by ordinary citizens include positive attitudes towards science and technology, and scientific skills that can be utilized in everyday life and work place such as problem solving and critical thinking skills. These kinds of knowledge and skills can be called *core skills* that can be developed through science education.

Science Education Curriculum for Developing Core Skills

8. In order to foster cores skills, science education at the basic education level today should include at least two elements: core skills that are required by any citizens to participate in the society such as problem solving and critical thinking skills; and basic science concepts and principles that are required by those students who wish to further study science to be a professional in the science-related fields. Thus, it is critical to balance the two aspects in science education curriculum at the basic education level.

9. By strengthening quality education at the basic education level and progressively strengthening specialized science education at higher levels, it will be possible to nurture a critical mass of scientific literate citizens and to develop scientific and technological professionals who can develop new products and assimilate innovative ideas from other countries.

Teaching and Learning Methods Effective for Developing Core Skills

10. Two major theories are reviewed to discuss effective teaching and learning methods in science education to develop core skills.

Science Education as Conceptual Change

11. In the conceptual change model, it is important for learners to be allowed to develop scientific concepts by modifying pre-instructional conceptions. In order for conceptual change to occur, first, learners need to be made aware of existing concepts they already have. A teacher must be able to: (1) conjecture what kinds of cognitive conflicts that learners are faced with, in other words, understand what pre-instructional conceptions that learners have and how these misconceptions hamper their understanding of scientific concepts to be taught; (2) provide the learners with concrete ideas which allow them to resolve the cognitive conflict; and (3) provide them with scientific framework/concepts that can allow the leaners to modify the pre-instructional conceptions to scientific conceptions. Therefore, science teachers must have sufficient science subject knowledge and instructional capacity that is based on cognitive science perspectives.

Science Education as Crossing Cultural Borders

12. There is another cognitive explanation where science is regarded as a kind of culture. In this model, science education is regarded as a process of acquiring the culture of science. Hence, science education must deal with issues of transition between the culture of science and that of learners' life-world, which is called "cultural border crossing". Because the culture of science is greatly influenced by the Western culture, the border crossings are likely to be felt more difficult by children who come from the cultures that are different from the Western culture. Therefore, one of the most important role of teachers is to be a guide for students to cross the border in science learning.

Experience in Science Education Development in Japan

Characteristics of Japan's Science Education Curriculum

13. Science education for ordinary citizens was introduced in comparatively earlier time in Japan. 'School Science' was introduced in 1886 at the primary level. The course content of School Science paid particular attention to the linkage between science and the nature and natural phenomena that children can find in their daily life. School Science has put a strong emphasis on hands-on activities such as observations and experiments.

Unique Features of Japan's Science Lesson

14. In lesson delivery for School Science, teachers pay special attention to bringing out learners' ideas and opinions so that they can understand learners' pre-instructional conceptions and how they have been formed. One of the important roles of teachers is not to give a correct solution, but to let the learners find a solution.

15. The TIMSS 1999 Video Study which compared eighth-grade science lessons conducted by teachers in five countries, has concluded that content and concepts to be taught in the science curriculum of Japan are carefully selected so that teachers can concentrate on a few essential concepts and spend time enough to foster scientific attitudes and skills of the students by allowing them to discuss and think the linkages between data, evidence and scientific concepts.

Study of Instructional Materials

16. An intensive study of instructional materials is considered as the key to a successful lesson delivery in Japan. The purpose of the study of instructional materials is for teachers to deepen the understanding of the subject content and to improve instructional skills bearing in mind learners' realities and developmental stages. It is also important for teachers to prepare concrete measures to allow learners to modify their pre-instructional conceptions to scientific conceptions.

Lesson Study

17. Lesson Study, a form of professional development for teachers, is widely practiced in Japan. Lesson Study provides teachers with opportunities to improve skills necessary for lesson delivery. Lesson Study basically consists of three steps: 'Plan', 'Do', and 'See'. Through the reflective discussions in the 'See' stage, teachers can learn not only how to improve the particular lesson, but also general instructional skills and knowledge which can be applied to other lessons.

Science Education Reform in Africa

ASEI-PDSI Approach

18. The first JICA-supported project aimed at strengthening mathematics and science education in Africa started at Kenya in 1998. Since then, more than 10 countries in Africa have implemented projects aimed at strengthening mathematics and science education. The projects assisted those countries in adopting a learner-centered teaching and learning method, which is called 'ASEI-PDSI approach' to improve the capacity of teachers to deliver lessons. 'ASEI' is an abbreviation of 'Activity', 'Students', 'Experiments', and 'Improvisation'. PDSI is an abbreviation of 'Plan', 'Do', 'See', and 'Improve'. PDSI is a continuous reflection process, which allows a teacher to improve the particular lesson, subsequent lessons, and lesson delivery skills in general.

Establishing a System for Continuous INSET

19. The SMASSE Project endeavored to establish a system for continuous INSET that allows teachers to participate in INSET every year. The Project established a two-tier cascading INSET system where National Trainers train District Trainers, and then the District Trainers train mathematics and science teachers.

Experience Sharing on ASEI-PDSI Approach in Africa

SMASE-WECSA Association

20. Based on the successful implementation of the SMASSE Project, Kenya's experience in establishing a continuous INSET system to disseminate the ASEI-PDSI approach was shared with other countries in Africa through the network of the SMASSE Western, Eastern, Central, and Southern Africa (WECSA) Association. The Association aimed to be a forum for administrators and professionals of Ministries of Education in Africa to share experiences and to discuss issues of mathematics and science education.

21. Other major activities of the SMASE-Association include the following: (1) Training for key INSET trainers from member countries; (2) Technical assistance for member countries; and (3) Technical exchange workshops. SMASE-WECSA activities are expected to play a critical role in improving science and mathematics education in Africa by facilitating experience sharing and peer learning in the African Continent.

Impacts and challenges of ASEI-PDSI Approach

22. Evaluation on the impact of the ASEI-PDSI approach was conducted by some of the SMASE-WECSA member countries. All the countries who conducted the evaluation have shown improvements in the quality of lessons delivered by teachers who have participated in INSET. However, some weaknesses have been also identified. Major ones include the following:

(1) There are many practical activities that do not require learners to think. In many cases, teachers do not wait for learners to think and to find solutions by themselves.
(2) There is no bridging between practical activities and scientific concepts. If any, the bridging is not well structured. Moreover, activities in lessons are sometimes irrelevant to the lesson objective.
(3) Many teachers still do not understand the importance of bringing out learners' ideas.
(4) The ASEI-PDSI approach is not implemented in everyday classroom situation.

Conclusion

23. I argue that the quality of science education at the basic education level is critically important as science education at that level can effectively fosters core skills such as scientific thinking skills. Science education at the basic education level not only develops core skills but also lay the foundation from which future scientific personnel can be nurtured. The quality of lesson delivery also needs special attention. Science lessons should deal with students' pre-instructional conceptions and cultural difference properly. In order for teachers to conduct such an effective lesson, it is important for them to bring out learners' ideas and opinions. In order to learn not only from theories but also from actual experience on the ground, it is important to create a forum where African countries can share experiences and good practices to bring about improvements in teaching and learning in science education in Africa.

3. INTRODUCTION

3.1. Overall Purpose of the Study

24. This study discusses what kind of science education is needed for effective scientific and technological development in Africa. The study mainly discusses two aspects of science education: nature of science curriculum; and effective teaching and learning methods.

3.2. Importance of Science Education in Africa

25. It is widely acknowledged that science education plays a crucial role in developing human resources necessary for science and technological development. A good science education is considered to lay a solid foundation for scientific and technological development. Hence, many African countries have attempted to strengthen mathematics and science education in order to develop human resources that can contribute to industrial development through scientific and technological development. Science education contributes not only to laying the foundation for human resources that are directly involved in science and technological development such as scientists, researchers, engineers, etc., but also to fostering core skills such as scientific thinking skills and problem solving skills, referred to as scientific literacy for ordinary citizens to participate in the society and work places.

3.3. When and What Kind of Science Education?

26. As a result of the remarkable progress in the universalization of basic education in Africa, many African countries have been shifting the focus of education on post-basic education. While it is important to nurture elite scientists and engineers by strengthening upper secondary and tertiary education, providing quality science education at the basic education level, is even more important for scientific and technological development (Caillods et al., 1996: 202). It is thus necessary to consider when and what kind of science education should be provided to facilitate scientific and technological development.

27. In addition, recent development in research on cognitive science has revealed a mechanism of knowledge construction and conceptual formation of children. Based on these theories, many countries have introduced learner-centered teaching and learning methods.

28. This study discusses and proposes a kind of science education that contributes to scientific and technological development. In particular, an emphasis is placed on the importance for children to learn science at the basic education level. Based on experiences in science education development in Japan and Africa, the study proposes teaching and learning methods that can effectively foster core skills such as scientific thinking and problem solving skills.

4. LITERATURE REVIEW

4.1. Core Skills for Scientific and Technological Development

29. Initially science in the school curriculum was learned mainly by those who wish to study science at the university and to work in the science-related fields such as scientists, researchers, engineers, etc. (Holbrook, 2010: 80) Hence, science had a nominal place in the primary years of schooling before the 1980s (Fensham, 2004: 9).

30. Due to the recent change of the world where any issues in the society depend on science to some extent such as climate change, environmental sustainability, etc., all citizens are required to have a certain level of scientific knowledge and scientific thinking skills (Gluckman, 2011: 3).

31. Such a change requires science education to change its nature. Previously, the major purpose of science education was to teach the basics of science for those students who wish to further study science and engineering. Hence, this kind of science education focuses on learning scientific knowledge that is expected to be the foundation for the future study of science. However, scientific knowledge and skills required by ordinary citizens should be different. They should include positive attitudes towards science and technology, and scientific skills that can be utilized in everyday life and work place such as logical reasoning, problem solving, critical thinking skills, etc. These kinds of knowledge and skills can be called *core skills* that should be developed through science education.

4.2. Science Education Curriculum for Developing Core Skills

32. The major purpose of science education used to be to lay the foundation for the further professional study of sciences. This kind of science education can be called 'educating the workforce' or 'pre-professional education (Jenkins, 2003: 12; Gluckman, 2011: 3). On the other hand, another kind of science education for ordinary citizens to learn core skills such as scientific thinking and scientific attitudes, is called, "science education for scientific literacy", or "citizen-focused objectives of science education" (Jenkins, 2003: 11-12; Gluckman, 2011: 3).

33. Major goals of science education at the basic education level today should include at least the two elements mentioned above: to acquire core skills that are required by any citizens to participate in the society such as skills of logical thinking, problem solving, critical thinking, etc.; and to learn basic science concepts and principles that are required by those students who wish to further study science to be a professional in the science-related fields. Thus, it is critical to balance the two aspects in science education curriculum at the basic education level.

34. IIEP (1996: 15) argues that investments to the tertiary education were sometimes disproportionate to the benefits they delivered and that primary and secondary science remained underdeveloped, which may have slowed down the process of learning and gradual assimilation of science and technology by the overall population. Then, based on the experience of high-performing economies such as South-East Asian economies, IIEP concludes as follows:

> The conclusion was reached that the most attractive science education policies, which will contribute most to development, are those that place their stress on two overriding objectives, these are: providing basic science education for all (desirably including a technological element) to give a secure foundation to the largest possible group; and progressively investing in more specialized science education at higher levels (in the upper secondary cycle and in higher education) (IIEP, 1996: 202).

35. Moreover, there are other reasons that support the importance of science education at the basic education level. First, children who love science can be candidates for future scientists and engineers. Thus, it is important that positive attitudes towards science should be formed at an early age. In this respect, children's environment, in particular, family and home environments are quite influential. However, in developing countries where there are many families that do not afford to create a scientifically conducive environment for their children, primary science education plays a critical role.

36. Second, findings in cognitive science justify the necessity of starting science education at an early age. Children are in general interested in their environment. They are eager to know how things happen and work, and try to understand daily phenomena in their own ways. They construct own 'theories' to make sense of what they see around their environment. Such explanations and 'theories' are called 'children's science' or 'children's scientific ideas'. Such children's ideas "tend to be limited to concrete, observable features and may be inconsistent with the formal theories of conventional science" (NCCA 2011). Once these ideas are formed, children tend to keep the ideas, which often hampers a proper understanding of scientific concepts. Thus, it is necessary for children to be guided by appropriate persons who can make children aware of these ideas and to have these ideas challenged and examined so that children are helped to modify their ideas to develop more scientific understandings. It should be done at the time when those pre-conceptions are formed (Harlen, 1987: 57). This should be one of the important roles of primary education.

4.3. Teaching and Learning Methods Effective for Developing Core Skills

37. What kind of teaching and learning methods can effectively equip children with core skills? In this section, two major theories are reviewed to discuss effective teaching and learning methods in science education to develop core skills.

4.3.1. Science Education as Conceptual Change

38. Constructivism is one of the major perspectives on learning. From the perspective of constructivism, learners are not a passive recipient of knowledge, but they construct knowledge by linking new ideas and experiences with what learners already know. "A fundamental assumption of constructivism is that learners construct understanding through interactions with the physical and/or social environment" (Liang, 2005: 1145). One of the influential models in science education is the conceptual change model[i].

39. From the perspective of the conceptual change model, children bring 'views' with them to science lessons that are logical and coherent to them. These 'views' are formed through children's experiences even before they learn the concepts in the classroom. These 'views' are called 'children's science' or 'pre-instructional conceptions' [ii] (Gilbert et al. 1982: 62; Duit 2003: 671). Children's science or pre-instructional conceptions have a considerable influence on how and what children learn from their classroom experiences (Gilbert et al. 1982: 631). In the conceptual change model, learners are allowed to develop scientific concepts by modifying pre-instructional conceptions. In order for conceptual change to occur, first, learners need to be made aware of existing concepts they have, and then, the following four conditions must be met: (1) Learners must feel dissatisfaction with the existing concepts (pre-instructional conceptions); (2) A new concept must be intelligible; (3) A new concept must appear initially plausible; and (3) A new concept should be fruitful, namely, a new concept can resolve the problems that the existing concepts cannot (Read, 2004: 4-5).

40. Because several conditions must be met in order for conceptual change to occur, external supports, in most cases, are essential. This is where teachers should play a critical role in science education. A teacher must be able to: (1) conjecture what kinds of cognitive conflicts that learners are faced with, in other words, understand what pre-instructional conceptions that learners have

and how these misconceptions hamper their understanding of scientific concepts to be taught; (2) provide the learners with concrete ideas which allow them to resolve the cognitive conflict; and (3) provide them with scientific framework/concepts that can allow the leaners to modify the pre-instructional conceptions to scientific conceptions（Uchida, 2008: 9）. Therefore, science teachers must have sufficient science subject knowledge and instructional capacity that is based on cognitive science perspectives.

4.3.2. Science Education as Crossing Cultural Borders

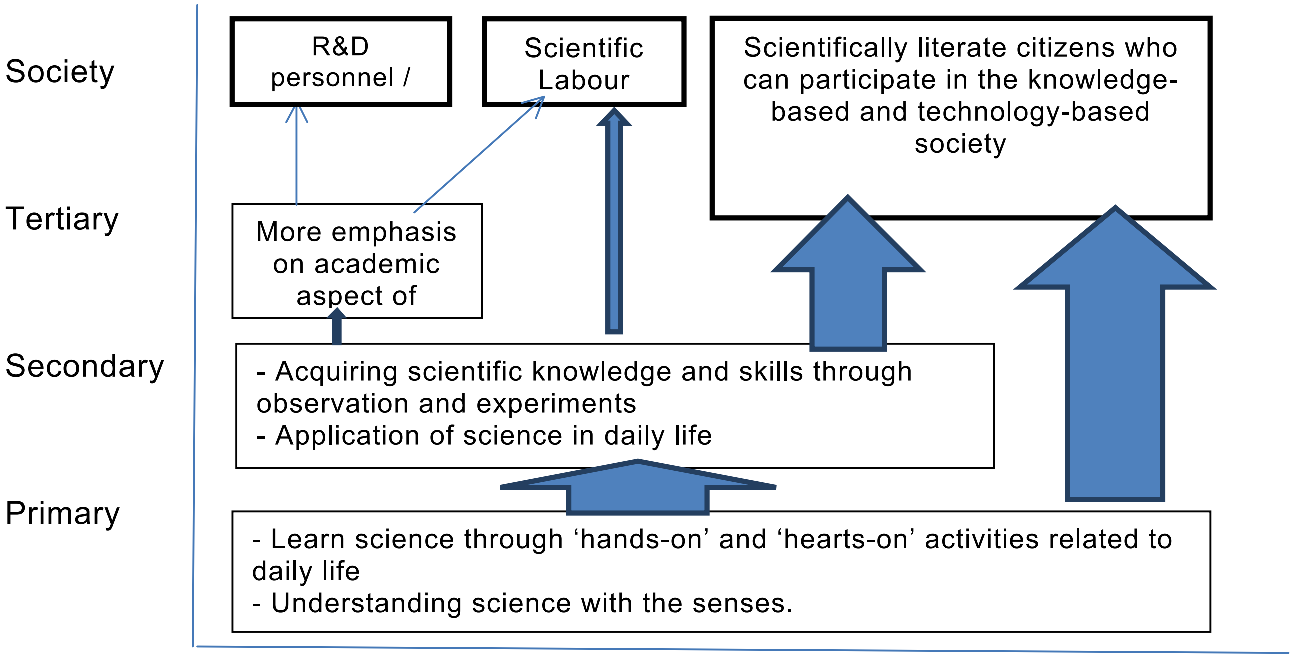
41. There is another cognitive explanation in science education where science is regarded as a kind of culture. In this context, culture is defined in a broad sense as “an ordered system of meanings and symbols, in terms of which social interaction take place” (Geertz, 1973, quoted by Aikenhead et al., 1999: 271) and science is regarded as “the culture of scientific community” (Ogawa, 1999: 1). Then, science education is regarded as a process of acquiring the culture of science. Hence, science education must deal with issues of transition between the culture of science and that of learners’ life-world, which is called “cultural border crossing” (Aikenhead et al., 1999: 271).

42. In this explanation, when the culture of learners’ life-world and the culture of science are compatible, or when learners can easily adapt themselves to the culture of science, it is not difficult for them to cross the border between the two cultures. However, when the life-world culture of the learners is incompatible with the culture of science, or when the learners cannot easily adapt themselves to the culture of science, they are likely to have difficulties in learning science because of the difficulty in crossing the cultural borders (Aikenhead et al., 1999: 274). According to Aikenhead et al. (1999: 270), learner’s success in science courses depends on the following: “(a) the degree of cultural difference that students perceive between their life-world and their science classroom, (b) how effectively students move between their life-world culture and the culture of science or school science, and (c) the assistance students receive in making those transitions easier”.

43. Because the culture of science is greatly influenced by the Western culture, the border crossings are likely to be felt more difficult by children who come from the cultures that are different from the Western culture such Africa and Japan. Children in some African countries may be faced with even greater difficulties in learning science when the language they use in the school is different from the one they use at home because those children have difficulties not only in understanding teacher’s instructions, but also in explaining their opinions and ideas, which is critical to learn school science. In this way, cultural barriers between school science and children’s life-world may make it more difficult for children in Africa to learn science. Therefore, it is crucially important for teachers in Africa to be a guide for students to cross the border in science learning.

4.4. Emphases in Science Education and Human Resources Development

Figure 4.1: Emphases in Science Education and Human Resources Development



Source: Developed by the author

44. Figure 4.1 illustrates the major emphases in the science curriculum at different levels. As children at the primary level are generally not conversant with abstract thinking, it is necessary for them to learn science by relating it with actual things and phenomena in their daily life. Hence, 'hands-on' and 'hearts-on' activities that stimulate psychomotor and affective domains should be emphasized in lessons. However, it should be noted that these activities must also include the 'minds-on' aspect to stimulate children's independent thinking. It is important for children to be provided opportunities to modify their 'children's ideas' to construct scientific knowledge.

45. Group work and whole class discussions are also recommended to provide students with opportunities to critically examine their own ideas and opinions. It is also important to provide learners with opportunities to apply the constructed knowledge to daily life situations and the society, for instance, by letting them explain phenomena with scientific knowledge. At the upper secondary and tertiary levels, systematic scientific knowledge and conceptual understanding need to be emphasized.

46. By strengthening quality education at the basic education level and progressively strengthening specialized science education at higher levels, it will be possible to nurture a critical mass of scientific literate citizens and to develop scientific and technological professionals who can develop new products and assimilate innovative ideas from other countries.

5. JAPAN'S EXPERIENCE IN SCIENCE EDUCATION

5.1. Characteristics of Japan's Science Education Curriculum

47. While, at the very beginning stage of modernizing its educational system in Japan, science education was mainly for those who wish to become scientists or professionals in science-related fields, science education for ordinary citizens was also introduced in comparatively earlier time in Japan. After the Meiji Restoration in 1868, "School Ordinance ("Gaku-sei" in Japanese)" was promulgated in 1872 and the modern education system was introduced to Japan. It was urgent for Japan, then, to assimilate scientific knowledge from the Western countries for her modernization. To that end, the Japanese government needed to urgently develop human resources that can understand and assimilate the Western modern science. Thus, at that time, the Japanese government put a premium emphasis on science education, which resulted in allocating almost 50% of the 8-year primary education curriculum hours to mathematics, science and technology-related subjects. Science was taught as separate science subjects such as Physics, Chemistry, and Natural History at that time (Itakura, 1968: 5-7; Tsukuba Association for International Education Studies, 1998: 163-174).

48. There was a change in the nature of the science curriculum in 1886. Natural science subjects at the primary level were integrated and replaced by the subject called 'School Science' ('Rika' in Japanese). The nature of 'School Science' was different from 'science' in the sense that the emphasis was placed on the relationship between daily life and science. The course content of School Science paid particular attention to the linkage between science and the nature and natural phenomena that children can find in their daily life.（Itakura, 1968: 5-7; Tsukuba Association for International Education Studies, 1998: 163-174）.

49. School Science in Japan has put a strong emphasis on hands-on activities such as observations and experiments. School Science for the lower grades (from the 1st grade to the 3rd grade) was introduced in 1941, which mainly dealt with the observation of nature（Itakura, 1968: 413）. Since then until 1991, School Science had been taught from the 1st grade (Tsukuba Association for International Education Studies, 1998: 165). In this way, the Japanese government paid special attention to science education at the primary level even before the 1960s while many other countries reformed and strengthen their science education at this level during and after the 1960s (Saruta, 2008: 42).

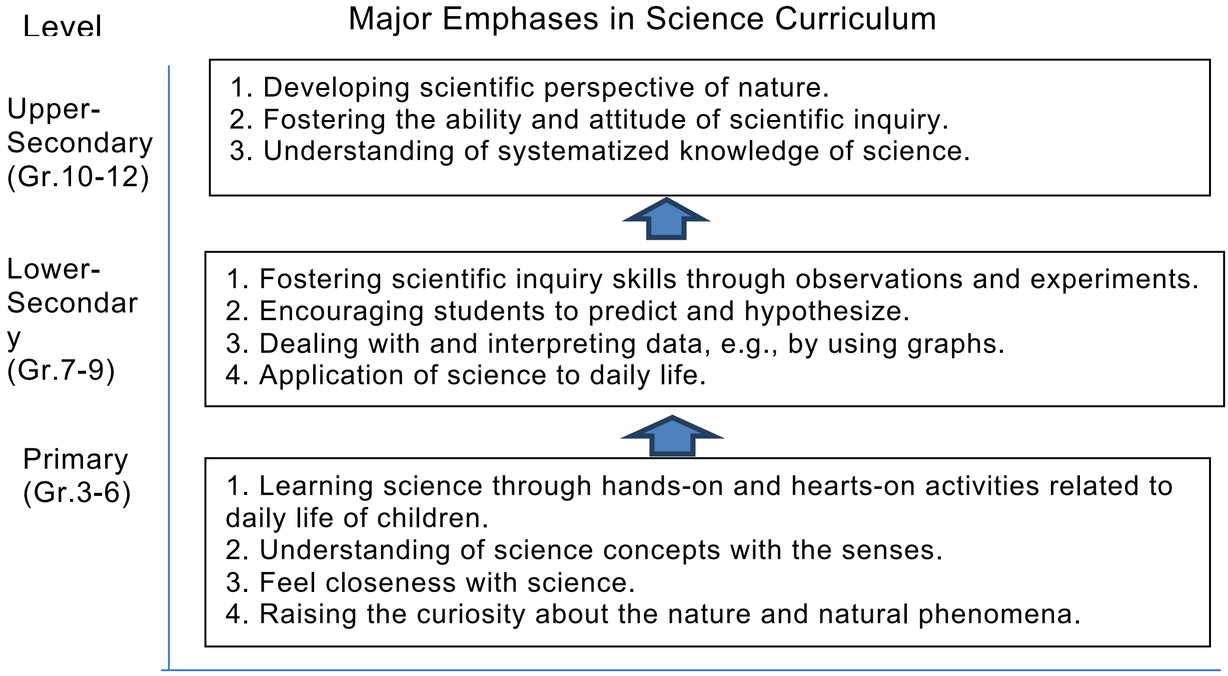
Table 5.1 Major Emphases of Primary Science Curriculum in Japan after World War II

Year	General Theme of the Curriculum	Major Emphasis in Science Curriculum	Characteristics of Science Curriculum
1947	- Child-centered curriculum.	- Daily life science	- Linking science with everyday life. - Problem-solving in a daily life.
1958	- Systematic learning	- Systematic learning of science	- Emphasis on the systematic organization of content. Content was arranged in accordance with a systematic order of basic scientific concepts.
1969	- Contemporization of education	- Inquiry-oriented science	- Influence of" New Science Movement" in the USA. - Learning through scientific inquiry. Emphasis on scientific methods such as observations and experiments. - Careful selection of contents by focusing on basic science concepts.
1977	- Stress-free education	- Reduction of the curriculum content	- Further careful selection of the curriculum content in order to lighten the burden for children. - Emphasis on the basic content as a citizen. - Cultivation of humanity
1989	- Respect to individualism	- Cultivating an eagerness to learn science	- Emphasis on familiarizing students with the natural world. - Science and Social Science are integrated at lower grades at elementary level as 'Life and Environment Studies'. - Number of hours and content for science were reduced to give more time for reflection for students.
1998	- Zest for living	- Curiosity and eagerness to learn science	- Enhance students' interest in nature - Intellectual curiosity and an individual eagerness to inquire into the natural world. - 'Integrated Study' was introduced from Grade 3 in elementary schools. - School days were reduced to six to five days a week. Number of hours was reduced by 10% more. Content of each subject area was also reduced by 30 %.

Sources: Adapted from IFIC-JICA (2004) and Pawilen et al. (2005).

50. After World War II, School Science Curriculum of Japan was revised about every ten years. Although major emphases of the curriculum have been changed based on the situation of Japan and the international trends as shown in Table 5.1, the major principle of School Science has been maintained that emphasizes the importance of relating science with everyday life issues and of including hands-on activities such as observations and experiments. Figure 5.2 illustrates the current major emphases in the science curriculum in Japan.

Figure 5.2 Current Major Emphases in Science Curriculum in Japan



Level | Major Emphases in Science Curriculum

Upper-Secondary (Gr.10-12)
1. Developing scientific perspective of nature.
2. Fostering the ability and attitude of scientific inquiry.
3. Understanding of systematized knowledge of science.

Lower-Secondary (Gr.7-9)
1. Fostering scientific inquiry skills through observations and experiments.
2. Encouraging students to predict and hypothesize.
3. Dealing with and interpreting data, e.g., by using graphs.
4. Application of science to daily life.

Primary (Gr.3-6)
1. Learning science through hands-on and hearts-on activities related to daily life of children.
2. Understanding of science concepts with the senses.
3. Feel closeness with science.
4. Raising the curiosity about the nature and natural phenomena.

Source: Developed by the author based on MEXT (2009a, 2009b, 2009c)
Note: The major emphases in the figure above do not cover all the emphases in the Course of Studies. Only major emphases that are related to the theme of this study are selected.

5.2. Characteristics of Japan’s Science Lesson Delivery

5.2.1. Unique Features of Japan’s Science Lesson

51. Regarding the ‘implemented curriculum’, namely, lesson delivery, in School Science, teachers pay special attention to bringing out learners’ ideas and opinions. In order to do so, it is critically important for teachers to provide learners with a problem that is interesting enough to motivate learners to think and discuss. By bringing out learners’ ideas and opinions, teachers can understand learners’ pre-instructional conceptions and how they have been formed. According to the nature of pre-conceptions that learners have, a teacher makes decisions on how to deal with the pre-conceptions to modify them to scientific conceptions. One of the important roles of teachers is not to give a correct solution, but to let the learners find or construct a solution (a scientific concept), for example, by posing questions, clarifying issues for learners to think, and sorting out similarities and differences in opinions raised by learners.

52. School Science curriculum at the primary level includes many practical activities in which learners are engaged for hands-on experiences. For example, pupils grow plants in the school garden to observe the growth; they feed small animals or insects to understand their features and natures; they conduct small-scale experiments by themselves, etc. As it is important for pupils to feel closeness with science at the primary level, it is also important for teachers to use materials and examples that can be found in the daily life of the pupils.

53. Some comparative studies delineate the characteristics of Japan’s science teaching and learning. For example, a comparative study on science textbooks used in Indonesia and Japan provides evidence to support the characteristics stated above. The study compared various kinds of process skills in the textbooks that pupils are required to apply. The results show that, while Indonesian textbooks require pupils to use basic scientific skills such as observing, inferring and

communicating, Japanese textbooks require pupils to use integrated skills such as formulating hypotheses, identifying variables, and interpreting data (Lumbantobing, 2004: 35-36).

54. Results of another comparative study on secondary science lessons also delineate some features of Japan's science lessons. The TIMSS 1999 Video Study was conducted to compare eighth-grade science lessons delivered by teachers in the US with science lessons delivered by teachers in the relatively high performing countries in science achievement tests, namely, Australia, Czech Republic, Japan and Netherland. The report summarizes the characteristics of the science lessons in Japan as follows:

> Japanese eighth-grade science lessons typically focused on developing a few physics and chemistry ideas by making connections between ideas and evidence through an inquiry-oriented, inductive approach in which data were collected and interpreted to build up to a main idea or conclusion. …, Japanese science lessons were found to be conceptually coherent with an emphasis on identifying patterns in data and making connections among ideas and evidence. Independent practical work played a central role in the development of main ideas. Before carrying out such activities, Japanese eighth-grade students were usually informed of the question they would be exploring in the investigation, and were sometimes asked to make predictions. During and after practical work, Japanese students were guided by the teacher or textbook in manipulating and organizing the data into graphs or charts and then interpreting the data. Discussions after independent practical activities typically led to the development of one main conclusion—the main idea of the lesson. …., all of the main ideas in Japanese science lessons were developed with the use of data and/or phenomena. In fact, all main ideas were often supported by more than one set of data or more than one phenomenon. Thus, it appears that few ideas were developed in Japanese science lessons, but each idea was treated in depth, with multiple sources of supporting evidence (NCES, 2006: 20).

55. From the results and observations above, it can be concluded that content and concepts to be taught in the science curriculum of Japan are carefully selected so that teachers can concentrate on a few essential concepts and spend time enough to foster scientific attitudes and skills of the students by allowing them to discuss and think the linkages between data, evidence and scientific concepts.

5.2.2. Study of Instructional Materials

56. In order to deliver lessons effectively, many Japanese teachers conduct an intensive study of instructional materials before lessons, which is called "kyozai-kenkyu" in Japanese. The purpose of the study of instructional materials is for teachers to deepen the understanding of the subject content and to improve instructional skills bearing in mind learners' realities and developmental stages, instructional methods, types of learning activities, and the goals of subjects (Hokkaido Education Research Institute, 2011). Special attentions are paid to the following perspectives in conducting the study of instructional materials: (1) whether the instructional materials are relevant and effective to achieving the objective of the lesson; (2) whether the materials are suitable for learners' developmental stages and for their interests; and (3) whether instructions and activities make the learners to think.

57. In order for learners to construct scientific knowledge and for conceptual change to occur in a lesson, it is necessary for teachers to provide the learners with the opportunities to express their views and opinions, in particular, their pre-instructional conceptions. Without knowing learners' pre-conceptions, it is difficult for teachers to allow learners to modify their pre-instructional conceptions to scientific conceptions. Thus, it is important to pose a problem that motivates learners to think, to predict the solutions, and to formulate hypotheses. In order to develop such a motivating problem, it is critically important for teachers to make well-thought-out preparations of lessons by studying instructional materials from child's viewpoints. It is also important for teachers to prepare concrete measures to allow learners to modify their pre-instructional conceptions to scientific conceptions. In this way, a study of instructional materials is considered as the key to a successful lesson in Japan.

5.2.3. Lesson Study

58. Lesson Study, a form of professional development for teachers, is widely practiced in Japan[iii]. As stated above, if the major focus of science lessons is to change pre-instructional conceptions of learners into scientific conceptions rather than merely to impart knowledge, science lessons can be regarded as the process of communication between the teacher and learners as well as among learners concerning instructional materials and learning activities. Lesson Study provides teachers with opportunities to improve skills necessary for enhancing such communications during a lesson. Lesson Study basically consists of three steps: ‘Plan’, ‘Do’, and ‘See’. A teacher, often in collaboration with peer teachers, prepares a lesson by conducting a study of instructional materials. The lesson is conducted in front of students in the actual classroom, which is observed by peer teachers. After the lesson, the teacher who has conducted the lesson and the peer teachers who have observed the lesson get together to discuss the lesson delivery regarding, for example, whether the way the teacher encouraged the students to express their opinions was effective, whether all the students understood the key question posed by the teacher, how the students reacted to the key question, how ideas of each student changed, and how effective the measures taken by the teachers was, etc. Through the reflective discussions, teachers can learn not only how to improve the particular lesson, but also general instructional skills and knowledge which can be applied to other lessons. Lesson Study is widely practiced in Japan. More than 99% of the elementary schools (Grades 1-6) and 98% of the junior high schools (Grades 7-9) conduct Lesson Study at least once a year, and more than 82% of the elementary schools and 54% of the junior high schools conduct Lesson Study at least five times a year (Chichibu, 2010).

5.3. Enabling Conditions for Effective Lesson Delivery in Japan

59. I think it is necessary to briefly describe some of the conditions conducive to delivering effective lessons in Japan. As stated in 5.2.1, concerning the science curriculum in Japan, concepts and content to be taught are carefully selected so that teachers can concentrate on a few essential concepts and spend time enough to foster scientific skills and attitude of the students. Other conditions that need to be noted are the classroom culture and the status and working conditions of teachers in Japan.

5.3.1. Classroom Culture in Japan

60. In the classroom in Japan, opinions and ideas of students are well respected and treated as such. In general, much attention is paid to the process of arriving at solutions. One of the important roles of a teacher in Japan is to facilitate discussions among the students by encouraging students to express their opinions and ideas and to challenge ideas each other so that students themselves can arrive at a correct solution through a consensus building process. Through such a process, teachers let the students realize the cognitive conflict between the pre-conceptions and the scientific conceptions.

61. Learning from mistakes is considered as one of the most important things in Japan. Students’ ideas and opinions that seem to be incorrect are also carefully discussed and challenged by the students each other. Teachers in Japan well recognize that it is important for students to understand how they have made mistakes and how they can correct the mistakes on their own because students need to learn how to find a correct solution on their own, which is one of the most important core skills. Hence, teachers study common misconceptions that students are likely to have so that teachers can assist the students to modify such misconceptions to correct scientific conceptions.

5.3.2. Good Image and the Status of Teachers

62. A teaching job is one of the most popular professions in Japan. Some of the reasons include the following: it is a job that can contribute to the public goods; it is a stable job; and the salary of a teacher is a slightly higher than that of public servants[iv]. Most teachers in Japan have chosen

a teaching job as a first choice. Hence, generally speaking, most of the teachers in Japan have a willingness to work as a teacher, and the capability of candidates of teachers is relatively high and the retention rate is high[v]. Regarding the qualifications, both primary and secondary teachers need to have basically at least a bachelor degree. The salary for primary and secondary teachers is almost the same. Hence, most primary teachers have chosen to be a primary teacher as a first choice because they love to teach small children.

5.3.3. Enabling Conditions Proposed for Teachers in Africa

63. In order to implement effective learner-centered teaching and learning methods in Africa, not only the pedagogical aspect, but also other enabling conditions for teachers need to be considered. For example, it is necessary to create a classroom culture that allows students to express their ideas and opinions freely, and to make a teaching job attractive by improving the image and the status of teachers so that teachers' candidates will choose the job as a first choice. In particular, as the quality of primary education is influential both in fostering core skills of children and in laying the solid foundation for national development, it is important to improve the status and working conditions for primary teachers so that capable students would wish to become a primary teachers. It is also recommended that teachers should be assessed based mainly on the quality of lessons they deliver and opportunities for teachers to improve the professional skills should be provided.

6. SCIENCE EDUCATION REFORM IN AFRICA

6.1. ASEI-PDSI Approach

64. The Japan International Cooperation Agency (JICA) has assisted more than 10 countries of Africa in improving the quality of science and mathematics education through strengthening the capacity of teachers to deliver lessons through INSET. The first JICA-supported project aimed at strengthening mathematics and science education in Africa, Strengthening of Mathematics and Science in Secondary Education (SMASSE), was started in Kenya in 1998. Since then, more than 10 countries including Burkina Faso, Ethiopia, Ghana, Malawi, Niger, Nigeria, Rwanda, Senegal, South Sudan, Uganda, Zambia, have implemented projects aimed at strengthening mathematics and science education.

65. The projects assisted those countries in adopting a learner-centered teaching and learning method, which is called "ASEI-PDSI approach" to improve the capacity of teachers to deliver lessons. 'ASEI' is an abbreviation of 'Activity', 'Students', 'Experiments', and 'Improvisation'. PDSI is an abbreviation of 'Plan (planning a lesson)', 'Do (carrying out the planned activities)', 'See (assessing students' understanding and evaluating the lesson)', and 'Improve (improving the lesson based on the evaluation)'. PDSI is a continuous reflection process, which allows a teacher to improve the particular lesson, the subsequent lessons, and lesson delivery skills in general (CEMASTEA 2005). By adopting this teaching and learning approach, those countries have made efforts to transform teacher-centered teaching and learning methods into learner-centered ones.

66. While the 'ASEI-PDSI approach' was developed to address challenges in teaching and learning in Kenya, this approach has been proved to be effective in other African countries which are faced with similar challenges in mathematics and science education. In those countries that have introduced the ASEI-PDSI approach, some improvements in lesson delivery have been observed. In the following sections, I will explain how this approach was developed in Kenya, how it spread to other African countries, and what outcomes have been observed.

6.1.1. Challenges in Science Education in Kenya

67. Before designing the INSET curriculum for the SMASSE Project in Kenya, a baseline survey was conducted in 1998/1999 by questionnaires, interviews and lesson observations to identify the causes of poor performances of mathematics and science in secondary education. The survey identified challenges affecting schools, students, and teachers of mathematics and science education in Kenya. The challenges were then categorized into two: those that can be dealt with by the project and those that cannot (Table 6.1).

68. In order to address some of these challenges, project activities were designed and an INSET curriculum was developed which. The INSET curriculum intended to improve teachers' attitudes, pedagogical knowledge and skills, subject content knowledge, and skills of making and utilizing teaching/learning materials.

Table 6.1: Challenges identified by the baseline survey

Challenges that can be dealt with by the project	Challenges that cannot be dealt with by the project
a) Negative attitudes of head teachers, teachers and subsequently, pupils and parents.	a) Lack of staff houses and other facilities and/or equipment textbooks; water, electricity.
b) Lack of appropriate teaching methodology	b) Poor communication and funding of school

- Pedagogical issues: teacher-centeredness. c) Mastery of subject content. d) Few or non-existent interactive fora for teachers. e) Inadequate assignments to students. f) Infrequent inspection from subject inspectors. g) Missing link between primary and secondary school (syllabuses) content levels. h) Lack of information about schools by communities.	activities and programmes. c) Interrupted school programmes –fees collection and arrears. d) Food, child labour, and other family problems. e) Teachers' poor working conditions and terms of services including incentives. f) Overloaded syllabi and timetables –work load. g) Unfair transfers. h) Stagnation in one job group (level). i) Provision of infrastructure and instructional materials and equipment to schools.

Source: Adapted from Kibe et al. (2008: 16-17)

6.1.2. Birth of ASEI-PDSI Approach

69. In the process of developing the INSET curriculum, the survey team realized that, although many of the teachers interviewed by the survey team had mentioned the importance of student's participation and practical activities in the lessons, most of the lessons observed were teacher-centered. Then, they agreed that the following four perspectives would be helpful for teachers to deliver student-centered lessons:

- from content-based to activity-based lessons;
- from teacher-centered to student-centered lessons;
- from lecture/theory-based to practice/experience-based lessons; and
- from conventional materials to improvised materials.

70. These four perspectives were symbolized as Activity, Students, Experiment and Improvisation, and embraced in the INSET curriculum. Detail explanation about each of the four perspectives is as follows (Takemura, 2008: 269-274).

a) **Activity:** As many teachers whom the survey team observed applied a lecture method in their lessons, the survey team felt that lessons should be activity-based. Lessons should have practical activities that allow students to be engaged in, to think, and to construct knowledge/concepts. Activities are not limited to hands-on activities. Activities must include minds-on activities that bridge practical activities with conceptual understanding. Minds-on activities include: to predict, to develop strategies for solving a problem, to identify commonalities and/or differences, to distinguish evidence from opinions, to identify the relationship between causes and effects, to explain phenomena scientifically, etc.

b) **Student**: Students should construct knowledge by themselves with the guidance of teachers. Teachers should guide students to arrive at conclusions. The process should be owned by students themselves. Hence, students must be at the center of lessons.

c) **Experiment**: Scientific knowledge is generated and/or discovered through experiments and observations. An experiment is one of the most effective tools for scientific inquiry. Through experiments and observations, hypotheses are tested to find scientific truths. Thus, science lessons should include experiments where necessary.

d) **Improvisation**: One of the reasons for using improvised materials is based on the necessity. Even when conventional science apparatus and/or learning materials are not available, students can still carry out small scale experiments with improvised apparatus and materials that are developed from local materials collected in learners' immediate environment. Another reason is to raise interest and curiosity of students by using materials that are familiar to students.

6.2. Establishing a System for Continuous INSET

71. The SMASSE Project in Kenya was aimed to improve the quality of mathematics and science education by equipping mathematics and science teachers with the ASEI-PDSI approach. In order to popularize the approach, the SMASSE Project endeavored to establish a system for continuous INSET that allowed teachers to participate in the training every year. The Project established a two-tier cascading INSET system where National Trainers train District Trainers, and then the District Trainers train mathematics and science teachers.

72. In establishing the system[vi] for continuous INSET, in order to ascertain the sustainability of the INSET system, the following issues were carefully considered: (1) The system should cover the whole nation so that the established system will be part of the regular programmes of the Kenyan government; (2) The system should be sustained by the resources of the Kenyan government; and (3) A monitoring and evaluation mechanism was incorporated so that the Kenyan counterparts themselves can identify needs and challenges of teachers to improve the quality of training.

6.3. Experience Sharing on ASEI-PDSI Approach in Africa

6.3.1. SMASE-WECSA Association

73. Based on the successful implementation of the SMASSE Project, Kenya's experience in establishing a continuous INSET system and the ASEI-PDSI approach was shared with other countries in Africa through the network of the SMASSE Western, Eastern, Central, and Southern Africa (WECSA) Association. The Association was aimed to be a forum for administrators and professionals of the Ministries of Education in Africa to share experiences and to discuss issues of mathematics and science education. The Association currently consists of 34 member countries (as of September 2011). Since 2001 administrators and professionals from the member countries have been brought together to the SMASE-WECSA Conference once a year to discuss issues relating to mathematics and science education and INSET.

6.3.2. Major Activities of SMASE-WECSA Association

74. In addition to organizing the SMASE WECSA Conferences, other major activities of the Association include the following (CEMASTEA, 2010):

(1)Training for key INSET trainers from member countries: Center for Mathematics, Science and Technology in Africa (CEMASTEA) started providing training for WECSA member countries in 2004 and the training has been organized every year since then. The major theme of the training centered on disseminating the ASEI-PDSI approach. More than 100 participants each year including pedagogical advisors (inspectors), trainers and teachers, participate in the training courses organized by CEMASTEA in Kenya. Until the end of 2010, 16 training courses were organized, which were attended by more than 1000 participants from WECSA member countries in Africa.

(2)Technical assistance for member countries: Since 2005, CEMASTEA has provided technical assistance services to WECSA member countries. Until 2010, 14 countries have benefited from this service. The technical assistance services include: project formulation, baseline and needs assessment survey, INSET curriculum design, development of training modules, monitoring and evaluation of project activities, impact assessment studies, and INSET management and facilitation.

(3)Technical exchange workshops: When needs arise, a workshop has been organized to discuss issues and to share experiences regarding a specific theme. For example, technical workshops was organized in 2009 at Swaziland to share Zambia's experience in Lesson Study for school-based CPD, and in 2010 at Zambia to discuss how to motivate students to think more deeply through a problem-solving approach.

In this way, SMASE-WECSA activities have facilitated experience sharing and peer learning in the African Continent. While sharing knowledge in the academic sphere is not uncommon in Africa, there are few opportunities for practitioners to share experiences. Hence, WECSA activities are expected to play a critical role in improving science and mathematics education in Africa.

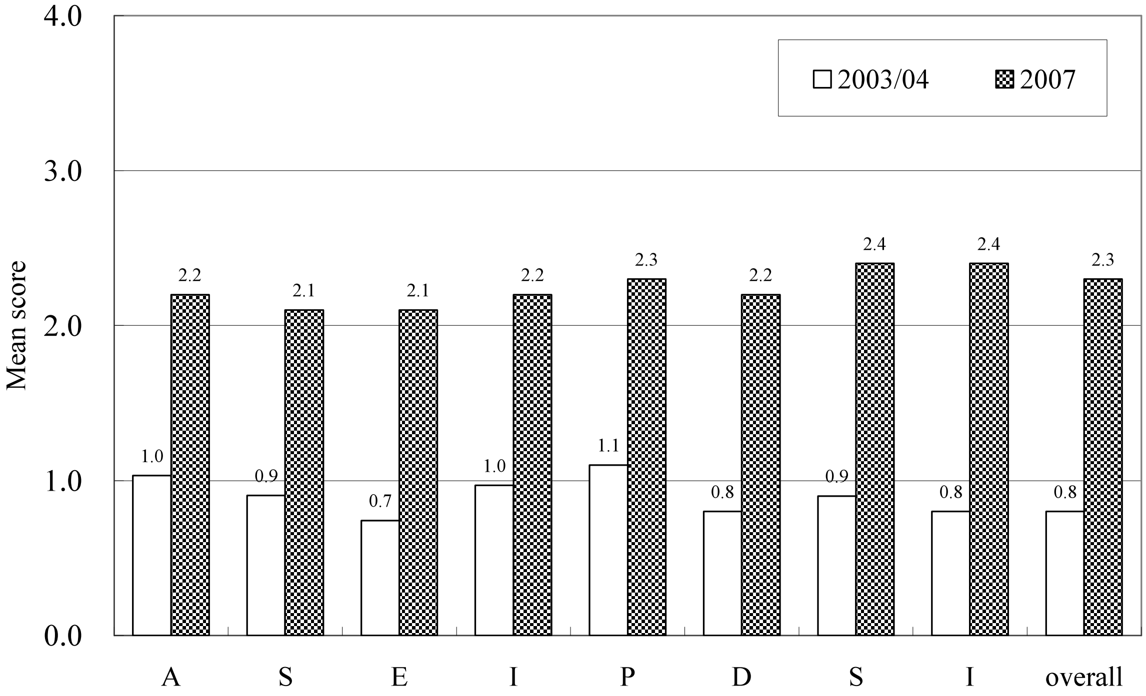
6.4. Impacts of ASEI-PDSI Approach

75. As explained in 6.1.2, the ASEI-PDSI approach was developed not from theory-based discussions, but from the analysis of actual challenges that mathematics and science teachers in Kenya were faced with. While it was developed based on the actual needs of teachers on the ground, if the approach is carried out properly, the approach is expected to be effective to deal with the issues raised by the conceptual change model in 4.3.1 and issues raised by the cultural border crossing model discussed in 4.3.2.

76. The SMASSE Project in Kenya has developed monitoring and evaluation tools for INSET and lesson deliveries. The tools evaluate the following aspects: (a) quality of national INSET, to be evaluated by the participants (District Trainers); (b) quality of District INSET, to be evaluated by the participants (science teachers) and National Trainers (CEMASTEA Staff); (c) quality of lessons conducted by teachers who have participated in District INSET, to be evaluated by National Trainers and the students who have attended the lessons. Other countries that introduced the ASEI-PDSI approach have developed their own monitoring and evaluation tools with reference to the tools developed by the Kenya SMASSE. By using these tools, all the countries have shown improvements in the quality of lessons delivered by teachers who have participated in INSET.

77. Some of the results of analyses on data obtained by the Kenya SMASSE Project regarding the impact of INSET on lesson delivery are shown below. The Kenya SMASSE Project developed three tools to measure the change in lesson delivery: (a) ASEI/PDSI Check List (Annex 1); (b) Lesson Observation Instrument (Annex 2); and (c) Questionnaire for Extent of Student Participation in Lesson (Annex 3). The tools (a) and (b) are used by lesson observers (National Trainers) and the tool (c) is answered by students who attended the lessons. Data were collected by using these three tools in 2003/04 and 2007 to measure the change in lesson delivery before and after the teachers participated in INSET. Three Districts were selected based on accessibility and ten secondary schools were identified in each District. By using the tools (a) and (b), lessons conducted by 45 teachers (19 teachers were District Trainers) were observed in 2003/04. In 2007, lessons conducted by 60 teachers including 45 teachers whose lessons were observed in 2003/04 were also observed for comparison. Regarding the tool (c), 1628 students in 2003/04 and 2231 students in 2007 answered the questionnaire. Out of 2231 students who answered the questionnaire in 2007, 1768 were taught by the 45 teachers whose lessons were observed both in 2003/04 and 2007. Rating scale used for the tools (a), (b) and (c) is 5-point scale of 0-4.

Figure 6.2 Comparison of mean scores on each aspect of ASEI-PDSI approach in 2003/04 and 2007

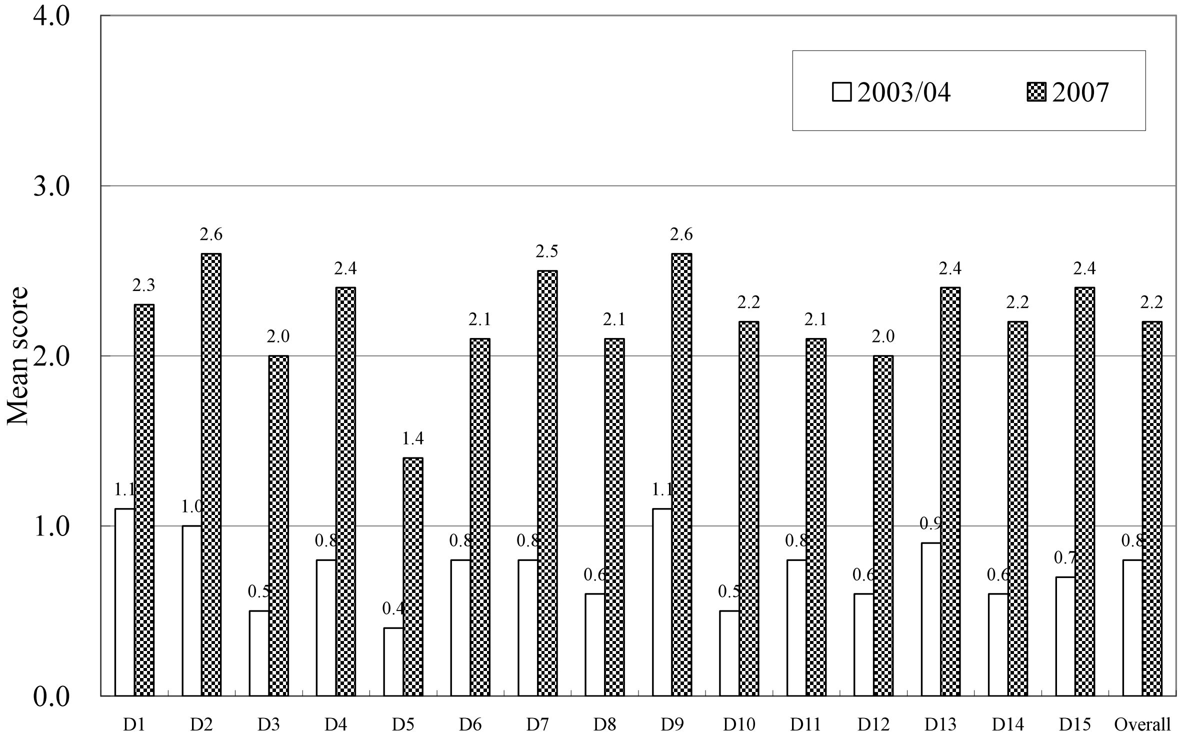


Source: SMASSE Project (2007: 13)

78. Figure 6.1 shows the comparison of the mean scores of teachers observed in 2003/04 and 2007 regarding each aspect of the ASEI-PDSI approach evaluated by National Trainers. Improvements are observed in all the aspects of ASEI-PDSI. The overall mean scores are 0.8 in 2003/04 and 2.3 in 2007. However, the score of the 'S' aspect in ASEI, namely, student-centeredness, is the lowest in 2007 and improvement between 2003/04 and 2007 is also the smallest.

79. By looking at the data in more depth, some weaknesses are identified. Figure 6.2 shows the comparison of mean scores of teachers on the various components of the 'Do' aspect of ASEI-PDSI Approach. The 'Do' aspect shows how the lesson is conducted. Among the 15 components of the 'Do' aspect, the score of the component D5 (Lesson encouraged students to express their prior experiences and explain their ideas related to the content) is the lowest and the smallest in the improvement between 2003/04 and 2007.

Figure 6.3 Comparison of mean scores on various components of 'Do' aspect of ASEI-PDSI approach in 2003/04 and 2007



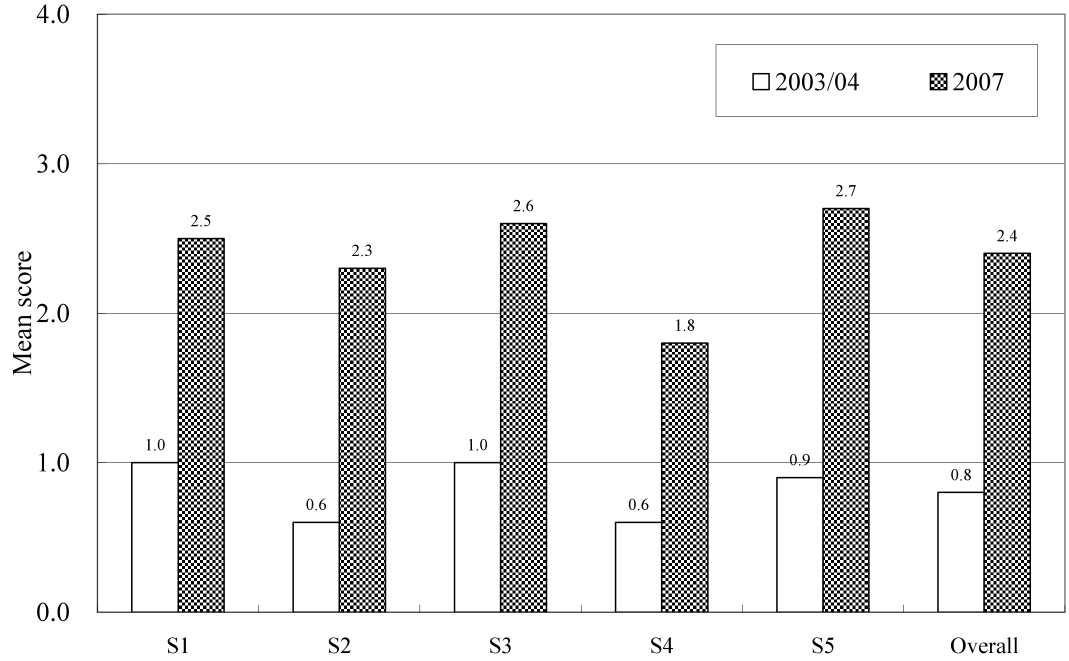
Source: SMASSE Project (2007: 16)

80. Figure 6.3 shows the comparison of the mean scores of various components of the 'See' aspect, which consists of the following five components.

-S1: Teacher supervised class work.
-S2: Teacher was attentive to the needs of students-low ability and high academic ability.
-S3: Teacher kept eye contract on students to monitor their feelings.
-S4: Teacher invited questions from students.
-S5: Teacher asked questions to check quality of understanding.

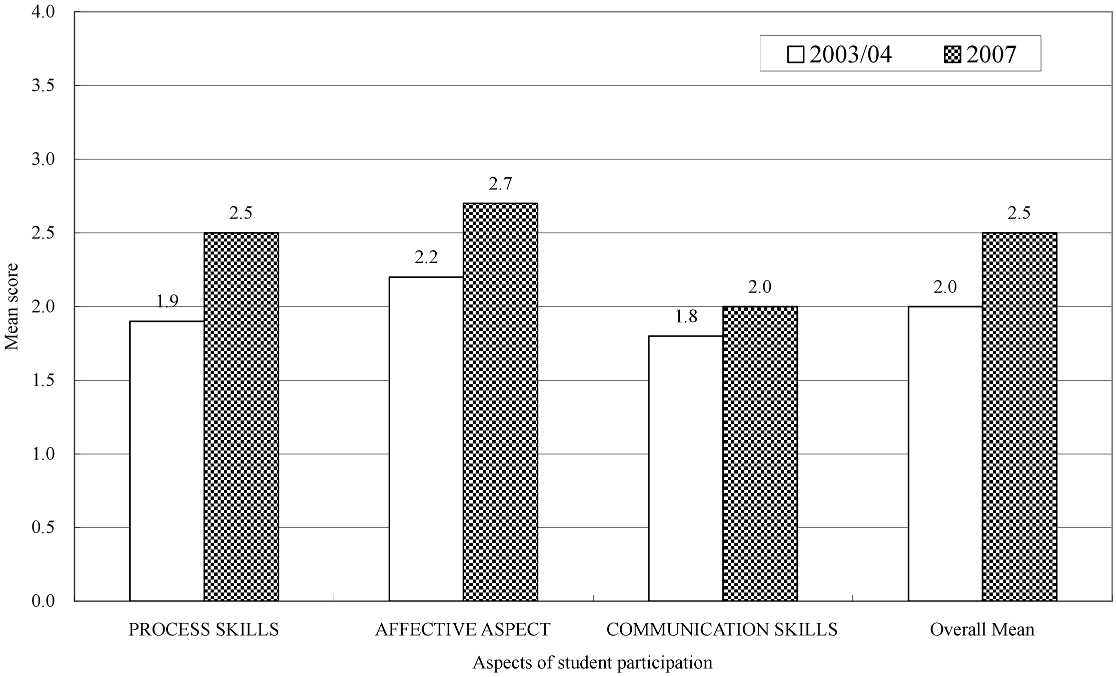
The mean score of S4 is the lowest both in 2003/04 and 2007. The improvement observed in S4 between 2003/04 and 2007 is also the smallest. The score of S5 is the highest and the improvement observed in S5 between 2003/04 and 2007 is also the greatest. These two results can be interpreted that, although teachers has become more conscious about the understanding of the students, opportunities for students to raise questions are still less than expected.

Figure 6.4 Comparison of mean scores on various components of 'See' aspect of ASEI-PDSI approach



Source: SMASSE Project (2007: 17)

Figure 6.5 Comparison of mean scores of various aspects of students' participation in lesson



Source: SMASSE Project (2007: 24)

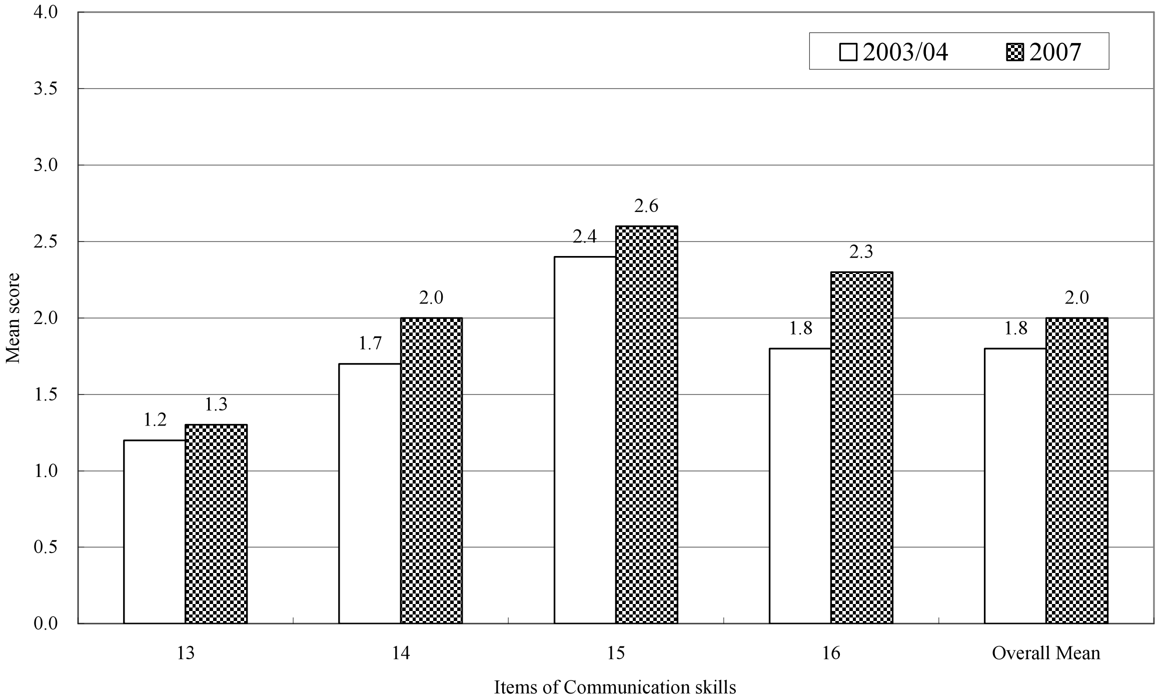
81. Figure 6.4 shows the comparison of mean scores of various aspects of students' participation in lesson. The questionnaire (Annex 3) is answered by the students concerning the following three aspects: process skills; affective aspect; and communication skills. Improvements are observed in all the three aspects between 2003/04 and 2007. Among the three, the mean score of the aspect of communication skills is the lowest both in 2003/04 and 2007 and the improvement between

2003/04 and 2007 is also the smallest. The aspect of communication skills consists of the following four components:

- Component 13: Asking questions.
- Component 14: Seeking clarification on areas not understood.
- Component 15: Answering questions posed by the teacher
- Component 16: Offering explanations to others.

82. Figure 6.5 shows the mean scores of each component of the aspect of communication skills. The mean score of the Component 13 is the lowest both in 2003/04 and 2007 and the improvement is the smallest. This result indicates that the students themselves think they do not ask questions during lesson.

Figure 6.6 Comparison of mean scores of various aspects of students' participation in lesson through communication skills in 2003/04 and 2007



Source: SMASSE Project (2007: 27)

83. The results shown above, in particular, in Figure 6.2, Figure 6.3 and Figure 6.5, indicate that, although general improvements in lesson delivery are observed between 2003/04 and 2007, namely, before and after the teachers participated in INSET, opportunities for students to raise questions and to express their ideas and opinions are still little. As it is critically important for teachers, through learners' opinions and questions, to understand misconceptions and cultural barriers that learners have, it is necessary to improve the attitudes and skills of teachers to encourage students to ask questions and to express their ideas.

6.5. Challenges of ASEI-PDSI Approach

84. In addition to the challenges identified by the survey conducted by the Kenya SMASSE Project, there are other challenges that are observed in other countries which have introduced the ASEI-PDSI approach. Major ones include the following.

(1) There are many practical activities that do not require learners to think. In many cases, teachers do not wait for learners to think and to find solutions by themselves.

This problem is caused by the lack of teachers in understanding the importance of learners' independent thinking because many teachers still seem to have a belief that providing learners with correct answers is the role of teachers. Teachers need to understand that it is important for learners themselves to understand how they make mistakes and how they can correct the answers. In order for teachers to be able to wait for students to find answers on their own, teachers need to have confidence in the ability of learners. To that end, it is important for teachers themselves to have an actual experience that learners can find answers on their own.

(2) There is no bridging between practical activities and scientific concepts. If any, the bridging is not well structured. Moreover, activities in lessons are sometimes irrelevant to the lesson objective.

This is caused by the insufficient understanding of the ASEI-PDSI approach. Some teachers seem to have understood that, as long as practical activities and experiments are included, the lesson is a good ASEI lesson. Thus, teachers need to understand the concept of the ASEI approach more deeply.

(3) Many teachers still do not understand the importance of bringing out learners' ideas.

Teachers have a belief about lessons that has been formed from their own experience when they were student. If the lessons they received when they were students is teacher-centered, even they know theories on constructivism and a learner-centered teaching and learning method, it is still difficult for them to change their lessons to a learner-centered one. They need to experience or, at least, observe an actual learner-centered lesson in order to help them change the belief.

(4) ASEI-PDSI approach is not implemented in everyday classroom situation.

This challenge is very common in many countries. This is because implementing the ASEI approach requires teachers to spend longer time for preparation until they get used to it. Many teachers also say that it takes longer to complete curricula than conventional teaching methods such as a lecture method. The nature of examinations also matters. For example, if the examinations mainly assess whether students know factual knowledge, teachers tend to impart to learners as much knowledge as possible, rather than allowing students to understand scientific concepts. Hence, examinations should have more questions in the examinations that assess whether students understand concepts or not, not whether they know many facts or not. In addition, in order to facilitate the implementation of the ASEI-PDSI approach in daily lessons, principals and inspectors/pedagogical advisors need to understand the effectiveness of the ASEI-PDSI approach so that they can encourage teachers to implement the approach. Moreover, it is necessary to identify good ASEI lessons conducted by teachers on the ground to share the lessons with other teachers. It is critically important for teachers to observe actual lessons because observing actual lessons is much more effective for teachers to change their belief than just understanding theories.

7. CONCLUSION

85. I argue that the quality of science education at the basic education level is critically important as science education at that level can effectively fosters core skills such as scientific thinking skills. Science education at the basic education level not only develops core skills but also lay the foundation from which future scientific personnel can be nurtured. The quality of lesson delivery also needs special attention. As explained in 4.3, science lessons should deal with students' pre-instructional conceptions and cultural difference properly. In order for teachers to conduct such an effective lesson, it is important for them to bring out learners' ideas and opinions. In order to improve the teaching and learning approaches in Africa, it is necessary not only to provide teachers with opportunities for continuous professional development including INSET, but also to create environment conducive to concentrating on teaching professions including policies, securing the status, and providing appropriate incentives. As Duit (2003: 684) pointed out, what is difficult is implementation of theories. Thus, it is important to learn from actual practices and experiences in order to bring about actual improvements in teaching and learning in Africa.

8. APPENDICIES

Appendix I

ASEI/PDSI Checklist

ASEI: Activity focused, Student centred learning, Experiments, Improvisation
PDSI: Plan, Do, See, Improve

Country………………… School……………………………………… Subject……………………

Topic/Subtopic………………………………………………………………………………………

Teacher Mr, Ms…………………………………Observer………………………………………

Class………………… Number of students………….. Date…………………………………

Please evaluate each of the following aspects of the lesson on the scale 0 – 4
(**0-not at all, 1-a little, 2-fairly adequately, 3-adequately, 4-a great deal**).

Plan		0	1	2	3	4
P1	The work plan took into account students' backgrounds such as learning difficulties, their needs/interests/misconceptions, growth of experimental skills and previous experience in relation to the topic					
P2	The work plan was appropriate and realistic in the light of the lesson content and students' abilities/skills/interest					
P3	Teacher prepared appropriate and adequate materials for students' use					
Do (Teach)	**Introduction**					
D1	Introduction incorporated previous knowledge/skills/everyday experience and linked them to the new topic					
D2	Introduction was clear on what the teacher wanted the students to learn					
D3	Introduction was stimulating enough to arouse the interest and curiosity of the students					
	Development					
D4	Lesson encouraged students to express their prior experiences and explain their ideas related to the content					
D5	Lesson encouraged students to give their own hypotheses/predictions and helped to discuss how they differed from those held by others and to verify them through experiments, facts, etc.					
D6	Lesson encouraged students to give their own observations/results in the experiment and to discuss how they differed from those of others					
D7	Lesson facilitated process skills such as observing, measuring, identifying variables planning experiments, etc.					
D8	Teacher dealt with students' questions, misconceptions and reinforced learning at each step					
D9	The lesson encouraged active participation of students as much as possible in the main teaching steps					
	Conclusion					

D10	Lesson encouraged students to draw conclusions					
D11	Teacher summarized the lesson and gave follow-up activities					
D12	The lesson assisted to view the content in relation to what they come across in the society					
D13	Teacher checked the accuracy correctness depth and appropriateness of the content through question and answer techniques					
	Class management					
D14	Teacher organized and conducted lesson taking into account the individual differences in student capability					
	Instructional materials/media					
D15	Teacher made effective use of the teaching/learning materials and media					
See (Evaluate)		**0**	**1**	**2**	**3**	**4**
S1	Teacher supervised class work					
S2	Teacher was attentive to the needs of students – low ability and high academic ability					
S3	Teacher kept eye contact on students to monitor their feelings					
S4	Teacher invited questions from students					
S5	Teacher asked questions to check quality of understanding					
Improve						
Im1	Teacher rephrased question or instructional statements as necessary					
Im2	Teacher interjected rightly and called to attention inattentive students					
Im3	Teacher gave further guidance to students on lesson activity(ies)					
Im4	Teacher made appropriate adjustments in the conduct of the lesson					

ASEI	**0-not at all, 1-a little, 2-fairly adequately, 3-adequately, 4-a great deal)**	**0**	**1**	**2**	**3**	**4**
Activity	The lesson was activity-focused: Evidence Practical work was conducted. Appropriate tasks for discussion were given					
Student involvement	The lesson was student-centred: Evidence Students were effectively encouraged to give their prior experiences and explain their ideas related to the content. Students were effectively encouraged to give their own hypotheses/predictions and helped to discuss how they differed from those held by others and to verify them through experiments, facts, etc. Students were effectively encouraged to give their own observations/ results in the practical work and to discuss how they differed from those of others. Students were encouraged to evaluate lesson					
Experiment effectiveness	The practical work helped to achieve the objective(s) of the lesson Evidence: Students were able to solve related problems. Students were able to make deductions from the practical					

	work. Students were able to verify hypotheses/ predictions.					
Improvisation	Improvisation was practiced during the lesson: Evidence: Modified/simplified experiment(s), small scale experiments were done Utilization of available materials in students' immediate environment Teacher produced and or utilized improvised equipment Students were able to use improvised materials effectively. Students' participation was enhanced/ increased.					

Appendix II

Lesson Observation Instrument

Country………………. School……………………………………. Subject……………………
Topic/Subtopic…………………………………………………………………………………
Teacher Mr, Ms……………………………………Observer……………………………………

Class………………… Number of students………….. Date…………………………………

Please indicate your assessment of the following aspects of the lesson by placing a tick in the appropriate box on the rating scale

(Rating scale: 0-poor; 1-fair; 2-satisfactory; 3-good; 4-very good)

I. Teaching procedure	Rating scale				
	0	1	2	3	4
Clarity/feasibility of lesson objectives a) Stated in simple and clear language b) Stated in terms of what learners are expected to achieve c) Achievable within stipulated time					
2. Appropriateness of lesson in terms of:					
i) Introduction Helps learners to focus on content of lesson Stimulating Makes reference to previous lessons, everyday experience					
ii) Content Related to learners' previous experience Geared to level of learners Stimulus variation (use of a variety of techniques) apparent in handling of content Teacher well versed in content					
iii) Gender 1. Examples free of gender bias 2. Questions distributed evenly 3. Motivational cues free of gender bias					
iv) Language • Voice well projected o Language appropriate to the level of learners o Teacher defines and explains difficult terms o Friendly in terms of communication with learners o Instructions given clearly and unambiguously					
3. Emphasis on main concept o Explanation and elaboration on main concept o Use of appropriate and familiar examples to illustrate main concept					
4.Lesson consolidation/summary o Recapitulation of main points o Reference to main concept, o Sufficient time for learners to ask questions seek clarification					
5. Achievement of set objectives Is apparent in: o Activities o Teachers questions o Students' questions					

o Students' answers o Level of enthusiasm					
II. Fundamental Technique/ methodology	Rating scale				
	0	1	2	3	4
1.Student involvement through questioning and discussion o Did the teacher ask questions? o Did students ask questions? o Were the learners involved in discussions?					
2.Student involvement in hands-on/minds-on activities o Were learners meaningfully engaged in learning activities? o Were the activities planned to arouse and sustain interest?					
3.Appropriateness of demonstrations, teaching aids and improvised materials o Materials, demonstrations appropriate for the purpose o Evidence of improvisation and economy in use of materials					
4. Appropriateness of teacher's attitude and expression o Did the teacher appear to be enjoying the teaching? o Was the teacher sympathetic to the needs and problems of the learners? o Did the teacher exercise patience with the learners?					
III. Management					
Distribution of time Was the time appropriately distributed o In the work plan? o In the execution of the lesson?					
Class control o Did the teacher ensure that all students were engaged in relevant learning activities? o Did the teacher handle disruptive behaviour appropriately?					
1. Use of students' opinions/ideas o Did the teacher actively solicit students' ideas on content being taught? o Did the teacher relate students' ideas to the content being taught? o Did the teacher discuss and correct students' misconceptions?					
Evaluation of the lesson by the teacher o Was evaluation incorporated in the plan? o Did the teacher actually evaluate the lesson? o Did the teacher indicate measures to be taken to improve future planning/execution?					

Additional comments……………………………………………………………………

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Appendix III

SMASSE PROJECT

QUESTIONNAIRE FOR EXTENT OF STUDENT PARTICIPATION IN LESSON

The aim of the SMASSE Project is to improve the quality of teaching and learning of mathematics and science in secondary schools. This questionnaire will be used to obtain information on the quality of participation in this lesson. The information will be treated with confidence and will be used solely for the purpose of strengthening science and mathematics education. Please give your honest response.
The following statements refer to your participation in the lesson that has just ended.
Read each statement carefully and evaluate your level of participation by writing a number in your ANSWER SHEET corresponding to your situation.

Key to level of participation: **EXAMPLE**

no participation [0] 13. Asking question
minimal participation [1] Your option is 2 (Average participation)
average participation [2]
above average participation [3] Write **2** in your answer sheet at below No. 13
maximum participation [4]

To what extent did you participate in each of the following during the lesson?

PROCESS SKILLS

1. Suggesting possible outcomes/results an experiment/activity [0][1][2][3][4]
2. Suggesting how to carry out an experiment/activity [0][1][2][3][4]
3. Making observations/taking measurement [0][1][2][3][4]
4. Recording observations/measurements/data [0][1][2][3][4]
5. Analyzing observations/measurements/data [0][1][2][3][4]
6. Discussing results of the practical activities and drawing conclusion [0][1][2][3][4]

AFFECTIVE ASPECT

7. Exercising care and ensuring safety of yourself and others during lesson activity [0][1][2][3][4]

8. Encouraging other students to make and record observations [0][1][2][3][4]
9. Helping the group to remain attentive on lesson activity [0][1][2][3][4]
10. Exercising patience in making observations, listening, explaining an idea, etc. [0][1][2][3][4]
11. Making honest record of your observations and calculations [0][1][2][3][4]
12. Accepting criticism from the teacher or from other students [0][1][2][3][4]

COMMUNICATION SKILLS

13. Asking question [0][1][2][3][4]
14. Seeking clarification on areas not understood [0][1][2][3][4]
15. Answering questions posed by the teacher [0][1][2][3][4]
16. Offering explanations to others [0][1][2][3][4]

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[i] The term 'conceptual change' is defined slightly different ways depending on authors and researchers. There are some papers that describe these differences such as Duit (2003), Read (2004), and Tyson (1996).

[ii] Other words are also used to express the concept of "children's science" such as naïve conceptions, misconceptions, alternative ideas, etc. Strictly speaking, these words suggest slightly different meanings, but I use these words interchangeably in this paper as those differences are not the focus of this study.

[iii] One of the classics of the literature on Lesson Study is STIGLER, J. W. et al. (1999).

[iv] The average salary of a teaching job was increased based on the law of the Securing Human Resources for Teachers that was promulgated in 1974. Although the average salary of teachers was higher than that of a public servant by about 20% in 1978, it was higher by about 4 % in 2007 due to several changes in the salary system of teachers.

[v] The retention rate has decreased recently because expectation of parents for teachers has become high recently and a teaching job has become more demanding job.

[vi] Refer to Kibe et al. (2008) and IFIC-JICA (2007) for the detail of the established system.