CICE Hiroshima University, *Journal of International Cooperation in Education*, Vol.19 No.2 (2017) pp.35 ～ 53

JICA's Support to Education in Africa in the Last Two Decades: Focusing on Mathematics and Science Education

Atsushi Matachi
Japan International Cooperation Agency (JICA)

Masato Kosaka
University of Fukui,
Former Affiliation: Associate Expert, Japan International Cooperation Agency (JICA)

Abstract

The objectives of this study are to identify achievements and challenges by analyzing the past technical cooperation projects implemented in Africa with the support of JICA in a cross-national manner, and to present possible measures to address some of the challenges identified above. The analyses for this study are based on mainly 28 terminal evaluation reports of JICA's mathematics and science technical cooperation projects in Africa. Through the comprehensive analysis, the following three achievements were identified: (1) INSET systems have been established; (2) Lesson delivery has improved; and (3) Students' participation in lesson improved. On the other hand, the following quantitative and qualitative issues were revealed: (1) Teaching methods learned at INSET are not implemented in the classroom as expected; and (2) Although changes in lesson delivery are observed, many of such changes do not necessarily lead to enhancing students' thinking process. Through the analysis of these issues, the paper proposes the possible measures to address the challenges.

Introduction

The World Conference on Education for All, held in Jomtien in Thailand in 1990, successfully built the consensus on the importance of basic education. Based on this international consensus, the Japan International Cooperation Agency (JICA) strengthened the technical cooperation (TC) in the area of basic education in the 1990s. JICA's TC in basic education focused on the three major issues: access to; quality of; and management of education.

In the 2000s, JICA increased the number of TC projects to improve mathematics and science education (MSE) which aimed to address the issue of quality of education. JICA-supported TC projects that are aimed to improve the quality of MSE consist of the two major components: to improve teaching and learning approaches; and to establish a system of teacher education and training so that teachers can be continuously engaged in professional development.

For the purpose of enhancing economic development, many African countries pay a particular attention to scientific and technological development. To that end, those countries attach an importance to developing scientific and technological human resources. For the development of human resources contributing to scientific and technological development, the quality of MSE at the basic education level holds a key (JICA 2015a). Hence, many countries in Africa have been making efforts to improve the quality of MSE at primary and secondary levels.

On the other hand, many of those countries are faced with challenges in MSE concerning curriculum policies, instruction practices and assessment, school context and instructional resources, and teacher education and development (Ottevanger, Akker & Feiter 2007).

When it comes to lesson delivery in the classroom, typical lessons observed in the classroom in many countries in Africa are lecture-type lessons where a teacher just explains concepts (Vavrus, Thomas & Bartlett 2011), demanding students to memorize facts and formulas and to give “chorus” answers with minimal activities carried out by students. It seemed that these kinds of lessons would not allow students to acquire scientific and mathematical thinking skills.

In order to improve the situation above, JICA has provided TC in improving the quality of MSE in Africa. The first TC project aiming to strengthen MSE in Africa was launched in Kenya in 1998. In order to address major challenges of MSE, the Kenyan government requested JICA to assist in implementing a TC project, which was aimed to improve a teaching and learning approach and to establish a sustainable in-service teacher education and training (INSET) system.

The project developed a learner-centered teaching and learning method (LCM), 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). This 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.

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

Based on the successful implementation of the project in Kenya, TC projects aiming to strengthen MSE were also implemented in other 14[1] countries in Africa. In order to evaluate the achievements and challenges of each project, JICA conducted terminal evaluations and summarized the results in terminal evaluation reports.

Objectives

According to the terminal evaluation reports, some achievements have been reported on each project. On the other hand, there are similar problems frequently observed in those projects. It is likely that there are common factors for those challenges because the educational situation and the implementation process of the project in those countries are quite similar. However, there has been no major study that analyzed those projects in a cross-national manner.

Based on the consideration above, the objectives of this study are to identify achievements and challenges by analyzing the past JICA's TC projects in a cross-national manner, and to present possible measures to address some of the challenges identified above.

Methodology

First, the terminal evaluation reports of MSE TC projects in Africa were selected. The literature was initially searched on JICA library using the search terms "terminal evaluation report" and "mathematics education, science education, teacher or lesson". After limiting the search to projects in Africa, this yielded 28 reports. The analyses for this study are mainly based on these 28 terminal evaluation reports of MSE TC projects in Africa. The list of the reports is shown in Table 1.

Second, the achievements and challenges were examined. The following steps were followed in the process of synthesizing the achievements and challenges presented in the reports. By referring to the qualitative data analysis method, sentences related to "achievement" were extracted and coded. Next, these codes were classified into categories according to the similarity. Then, these categories were named after the types of achievements. The same procedure was also used to synthesize the challenges.

Third, causes for the challenges were analyzed in consideration of the results of interviews conducted during the terminal evaluations and other opportunities for

[1] A TC project aiming to strengthen MSE was implemented in Sierra Leone from November 2011 to November 2014. However, this project is not included in the analysis because some activities planned in the project were not implemented due to the Ebola Outbreak in 2014 which forced JICA specialists to leave the country for several months.

Table 1. List of Terminal Evaluation Reports of MSE TC in Africa

	Country	Name of the project	Period
1	Kenya	Strengthening of Mathematics and Science in Secondary Education: SMASSE	1998.7-2003.6
2	Kenya	Strengthening of Mathematics and Science in Secondary Education (SMASSE) Project Phase 2	2003.7-2008.6
3	Kenya	Strengthening of Mathematics and Science Education (SMASE)	2009.1-2013.12
4	South Africa	Mpumalanga Secondary Science Initiative (MSSI)	1999.11-2002.3
5	South Africa	Mpumalanga Secondary Science Initiative Phase 2	2003.4-2006.3
6	Ghana	Improvement of Educational Achievement in Science, Technology and Mathematics in Basic Education(STM Project)	2000.3-2005.2
7	Ghana	Project to Support the Operationalisation of the In-Service Training Policy	2005.12-2008.11
8	Ghana	Project for Strengthening the Capacity of INSET Management	2009.6-2013.3
9	Malawi	Strengthening of Mathematics and Science in Secondary Education (SMASSE) INSET Malawi	2004.9-2007.9
10	Malawi	Strengthening of Mathematics and Science in Secondary Education (SMASSE) INSET Malawi Phase II	2008.8-2012.8
11	Uganda	Secondary Science and Mathematics Teachers' Project (SESEMAT)	2005.8-2008.8
12	Uganda	Secondary Science and Mathematics Teachers National Expansion Plan	2008.8-2012.8
13	Zambia	Strengthening of Mathematics and Science and Technology Education School-Based Continuing Professional Development Project (SMASTE-CPD)	2005.10-2007.10
14	Zambia	SMASTE School-Based Continuing Professional Development Project Phase II	2008.2-2011.2
15	Zambia	Strengthening Teachers' Performance and Skills (STEPS) through School-Based Continuing Professional Development Project	2011.10-2015.12
16	Mozambique	Strengthening of Primary Education in Gaza Province in Mozambique	2006.7-2009.7
17	Nigeria	Strengthening Mathematics and Science Education in Nigeria at Primary Level (SMASE Nigeria)	2006.8-2009.8
18	Nigeria	Project on Strengthening of Mathematics and Science Education in Nigeria Phase 2	2010.6-2013.7
19	Niger	Strengthening of Mathematics and Science in Secondary Education in Niger (SMASSE-Niger)	2006.9-2009.10
20	Niger	Improving the Teaching of Mathematics and Science in Secondary in Niger (PhaseII)	2010.3-2013.9

21	Senegal	Strengthening Mathematics, Science, and Technology Education Project (PREMST)	2007.12-2010.12
22	Senegal	Strengthening Mathematics, Science and Technology Project Phase 2 (PREMST 2)	2011.9-2015.8
23	Burkina Faso	Project of Teacher Training Improvement in Science and Mathematics at the Primary Level (SMASE – Burkina Faso)	2008.1-2011.1
24	Burkina Faso	Project of Teachers Training Improvement in Science and Mathematics at the Primary Level Phase II (SMASE–Burkina Faso II)	2011.12-2015.9
25	Rwanda	Strengthening Mathematics and Science in Secondary Education (SMASSE Rwanda)	2008.2-2011.1
26	Rwanda	Project of Strengthening School-based Collaborative Teacher Training (SBCT)	2013.1-2015.3
27	South Sudan[2]	Strengthening Mathematics and Science Education in Southern Sudan (SMASESS)	2009.11-2013.6
28	Ethiopia	National Pilot Project for Strengthening Mathematics and Science Education (SMASEE)	2011.3-2014.7

discussions with those who were involved in the projects.

Finally, recommendations for the measures to address the challenges are proposed.

Findings

Major achievements of the TC projects supported by JICA

Each report was coded in a manner as described below. For example, facts which are related to establishing an INSET system such as "A national trainer was appointed", "A committee was established" and "A training center was selected" were coded as "Improvement of INSET environment". Other achievements were also coded similarly.

Subsequently, "Improvement of INSET environment", "Development of INSET materials", and "Enhancement of capability of trainers" were sorted into a common category as a similar code. For the common category, it was defined that "INSET systems have been established". Similarly, a category that "Lesson delivery has improved" was extracted from lesson improvement identified by questionnaire surveys, class observations and interviews. The category "Students' participation has been improved" was also extracted from improvement in students' participation reported by questionnaires and interviews.

By applying the process described above, three major outcomes are identified as follows:

[2] South Sudan is excluded from the analysis in this paper because the South Sudanese Civil War began in December 2013 soon after the project came to an end in June 2013.

(1) INSET systems have been established[3];
(2) Lesson delivery has improved; and
(3) Students' participation in lessons improved.

(1) Major Achievement 1: INSET systems have been established.

Most of the countries established a system for INSET. Some of them successfully established a system that covers the whole area of the country.

(a) Areas targeted by the projects

Table 2. Characteristics of INSET Systems Established by MSE TC Projects in Africa

	Region-wide	Nationwide	Sustained
Burkina Faso		✔	-
Ethiopia	✔	In the process	✔
Ghana		✔	✔
Kenya		✔	✔
Malawi		✔	On-going Project
Mozambique	✔	-	-
Niger		✔	✔
Nigeria	✔	In the process	✔
Rwanda		✔	-[4]
Senegal		✔	On-going Project
Uganda		✔	On-going Project
South Africa	✔	-	-
Zambia		✔	✔

As shown in Table 2, in terms of the areas that the projects targeted to cover, there are two major types. While one type aims to establish a region-wide or province-wide INSET system in a country, the other one aims to establish a nationwide system. Except the two projects implemented in Mozambique and South Africa, all the other projects aim to establish a system nationwide.

In the cases of Nigeria and Ethiopia, the first-tier cascading training was conducted by National Trainers for all the Regional/Provincial Trainers, and then the second-tier training was conducted by Regional/Provincial Trainers for the trainers of the next level. The second-tier cascading training conducted only in a few selected Regions/Provinces

[3] "To establish a system" means that a country has developed the capacity to develop training materials to address specific needs of teachers, to implement training at national and local levels, to monitor the implementation of the training and to improve the training based on the results of the monitoring.
[4] Although the SMASSE Rwanda aimed to establish a cascading INSET system, the cascading INSET is not currently implemented on a regular basis. However, the school-based INSET system is being established.

as pilot activities during the project period under the agreement with the governments of those countries to continue the expansion of the system to other Regions/Provinces after the project period. Since the termination of the project, those two countries have been expanding the INSET system to other provinces in their own efforts.

(b) Sustainability

Out of 10 countries after having excluded the three countries in which TC projects are currently underway, six countries have been sustaining the INSET systems developed by the projects. For instance, Kenya has been sustaining INSET at secondary level with its own budget and personnel by changing the frequency of the training from annual-basis to experience-basis.

(2) Major achievement 2: Lesson delivery has improved.

Each project developed lesson observation sheets. By using the sheets, lessons conducted by the same teachers were observed at the beginning (base-line) and at the end of the project period (end-line). The average scores of all the teachers observed at the base-line and end-line are compared and, if the score at the end-line is higher than the score at the baseline, it was interpreted to have made improvements in their lessons. The results of the lesson observations conducted in each project are shown in Table 3, which shows that the improvements are observed in all the 10 countries that evaluated the change in lesson delivery. Details of the changes in lessons will be further discussed in "5. Discussions about the major issues".

Table 3. Improvement in Lesson Delivery

Country	Quantitative Data
Burkina Faso	Improved
Ethiopia	Not measured
Ghana	Improved
Kenya	Improved
Malawi	Improved
Mozambique	Not measured
Niger	Improved
Nigeria	Improved
Rwanda	Improved
Senegal	Improved
Uganda	Improved
South Africa	Not measured
Zambia	Improved

In addition to the changes in the lessons captured by quantitative data, qualitative changes were also observed as shown below:

i) Teachers conduct more group work and experiments. (JICA & Federal Ministry of Education, Federal Republic of Nigeria 2009; JICA, Ministry of Economic and Finance & Ministry of Education, Republic of Senegal 2010);
ii) Some teachers have come to use more teaching and learning materials (TLMs) during lessons. They improvised TLMs for students' activities and/or experiments (JICA & Federal Ministry of Education, Federal Republic of Nigeria 2009);
iii) Some teachers have come to pay more attention to thought processes and problems of learners (JICA & Ministry of Basic Education and Literacy, Burkina Faso 2010);
iv) Some teachers have come to make sufficient explanations during lesson delivery. (JICA & Ministry of Education, Republic of Rwanda 2011); and
v) Some teachers have come to make more communications with students. (JICA & Federal Ministry of Education, Federal Republic of Nigeria 2009).

(3) Major achievement 3: Students' participation in lessons improved.

Table 4 shows the changes of students' participation measured by student's self-evaluation that were conducted at the beginning and at the end of the projects. Only four projects have measured students' participation in lessons, namely, Kenya, Niger, Nigeria

Table 4. Improvement in Students' Lesson Participation

Country	Quantitative Data
Burkina Faso	Not measured
Ethiopia	Not measured
Ghana	Not measured
Kenya	Confirmed (Secondary) / Not confirmed (Primary)[5]
Malawi	Not measured
Mozambique	Not measured
Niger	Confirmed
Nigeria	Confirmed (Phase 1) / Not confirmed (Phase 2)
Rwanda	Not measured
Senegal	Not measured
Uganda	Confirmed
South Africa	Not measured
Zambia	Not measured

[5] It was not confirmed because of unavailability of disaggregated data for mathematics and science lessons at baseline conducted in 2009. However, comparing the data collected at midline in 2011 and those collected at endline in 2013, the average scores at endline are greater than those at midline in both of mathematics and science.

and Uganda. The self-evaluations include items that ask students whether they raise questions to teachers, whether they present their opinions to their peers, whether they communicate with other peers, etc.

In terms of qualitative changes in students' participation in lessons, the following changes were reported:

(a) Students' participation in a lesson improved (JICA & Ministry of Education, Republic of Kenya 2008; JICA & Federal Ministry of Education, Federal Republic of Nigeria 2009);
(b) Students came to think more independently (JICA & Ministry of Basic Education and Literacy, Burkina Faso 2010);
(c) Students came to ask questions more frequently (JICA & Federal Ministry of Education, Federal Republic of Nigeria 2009; JICA & Ministry of Education, Republic of Rwanda 2011);
(d) Interests of students in MSE increased (JICA & Ministry of Basic Education and Literacy, Burkina Faso 2010; JICA, Ministry of Economic and Finance & Ministry of Education, Republic of Senegal 2010); and
(e) More students came to choose Physics (JICA & Ministry of Education, Republic of Kenya 2008).

Major issues identified during/after the implementation of the projects

An examination into challenges was also conducted in a similar manner in each report as was done into the achievements. Discussions between the authors about the challenges have arrived at the idea that those challenges can be sorted into two categories, namely, "Quantity-related issues" and "Quality-related issues" as shown in Table 5. "Quantity-related issues" are those factors that may prevent teachers from implementing LCM in the classroom. "Quality-related issues" are those factors that may affect the quality of lessons implemented in the classroom.

"Quantity-related issues" are reported in 3 out of 9 countries. For example, in Malawi, it has been pointed out that "Many teachers consider it difficult to incorporate an ASEI-PDSI approach, namely, LCM, into their daily lessons" (JICA & Ministry of Education, Science and Technology, Republic of Malawi 2012). Also, in Kenya, it has been indicated that "An overloaded syllabus prevents teachers from applying LCM into their daily lessons" (JICA & Ministry of Education, Republic of Kenya 2008).

"Quality-related issues" are reported in 4 out of 9 countries. For example, in Ghana, it is reported that "Teacher's understanding about a good lesson is superficial, and, thus, teachers do not seem to contemplate why TLMs need to be used in a particular lesson, and that many of them tend to fall into a misconception that any lessons in which TLMs are used are good lessons" (JICA & Ghana Education Service 2009). Also, in Zambia, "After the project was introduced, teachers have come to ask more questions in the lessons than before. However, most of the questions are mainly to check whether the students know

Table 5. Issues Identified concerning Lesson Improvements

Country	Quantity-related Issue	Quality-related Issue
Burkina Faso	N/A	N/A
Ghana	N/A	Understanding about a good lesson is insufficient
Kenya	Overloaded syllabus prevents teachers from implementing ASEI-PDSI	N/A
Malawi	Many science and mathematics teachers consider it difficult to incorporate ASEI/PDSI into daily lesson	N/A
Niger	N/A	Further improvement of ability of teaching material development is required
Nigeria	N/A	N/A
Senegal	Further training is required for changes in the classroom	N/A
Uganda	N/A	Some teachers do not understand ALEI approach properly.
Zambia	N/A	Teacher's questions that demand students to think deeply and to use high order thinking skills are limited.

some facts or not and whether they understand the lesson or not, but the teachers do not frequently pose questions that allow students to think deeply" (JICA & Ministry of Education, Republic of Zambia 2010; JICA & Ministry of Education, Science, Vocational Training and Early Education, Republic of Zambia 2016).

Discussions about the major issues

As discussed in the previous section, there are two major issues in implementing the skills and knowledge teachers have learned in INSET, namely, quantity-related and quality-related ones. The two types of issues can be summarized as follow:

Major Issue 1: Teaching methods learned at INSET are not implemented in the classroom as expected.
Major Issue 2: Many of the changes observed in lesson delivery do not necessarily lead to enhancing students' thinking process.

As these two types of issues are critical and common to many countries, we further discuss and analyze the issues below.

(1) Major Issue 1: Teaching methods learned at INSET are not implemented in the classroom as expected.

This type of issue concerning the quantity-aspect is not only reported by the terminal evaluation reports, but also widely observed in many countries (SMASE-WECSA Association 2012). During the interviews conducted to evaluate the projects, similar comments were made in almost all the countries. The authors further asked the interviewees for the reasons for not implementing LCM they had learned. Major reasons identified from the interviews and reported during the Regional Technical Workshop conducted in 2012 are as follows (SMASE-WECSA Association 2012):

(a) Syllabi cannot be completed on time if LCM is used in daily lessons;
(b) Preparing a lesson applying LCM takes time;
(c) Examinations still focus on low-order thinking skills; and
(d) It is difficult to deal with a large class with LCM.

Let us discuss below each of the reasons above.

(a) Syllabi cannot be completed on time if LCM is used to daily lessons.

This reason is commonly reported during the terminal evaluation of the projects. Many of the interviewees have commented that it is difficult for them to complete the syllabus if they use LCM in the actual classroom although they understand that the pedagogical knowledge and skills they have acquired during INSET are useful and effective.

Generally speaking, in the practice of LCM, it is necessary for each student to go through a process in which each student own the learning task, struggle to find the solution, and discover the solution through carrying out activities such as experiments, presentations and debates. Hence, it is more effective for teachers to deal with one or at most a few concepts in a lesson so that students can construct the selected concepts on their own by engaging themselves in a variety of activities, rather than to cover as many concepts as possible in a lesson.

For example, the TIMSS Video Study conducted in 1999 explains that 65% of the content taught in a Japanese science class is basic content and that "Japanese students were supported in activities that focused on making connections among ideas, experiences, patterns, and explanations in more science lessons (72 percent) than in any other country except Australia." (Roth et al., 2006). Indeed, in Japan, because lessons are conducted with an emphasis on activities and discussions by the students themselves, concepts being covered in one lesson are carefully selected.

In contrast, as it is reported that "subject curricula have become overloaded, thereby exchanging quantity of learning matter against potential quality in learning" (World Bank 2008), curricula of many countries in Africa tend to include much content and, thereby, many concepts are taught in one lesson, probably, because the curriculum is designed based on the idea of knowledge transmission, rather than knowledge construction. Because of this, when teachers apply LCM in their daily lessons, many of them feel that they cannot complete syllabus. Hence, if a country wishes to propagate LCM to develop high-order thinking skills of students, it is needed to reduce the amount of content in the curriculum by selecting the basic and essential one.

(b) Preparing a lesson applying LCM takes time.

When implementing LCM, teachers need not only to prepare subject content to be taught beforehand but also to come up with questions that arouse students' interests, to develop main activities that motivate students to be engaged in, to anticipate students' thinking processes and common misconceptions, and to be prepared to deal with those misconceptions. In order to make these preparations in advance, teachers need to have not only a profound subject content knowledge, but also knowledge about their students including their common misconceptions and a deep understanding about the teaching materials to be used.

However, many teachers in developing countries are generally expected to teach the content in the syllabus as much as and as efficient as possible. Such a situation does not encourage teachers to provide students with a variety of activities to be engaged in. Thus, it may not be easy to prepare lessons applying LSM for those teachers who have been exposed to teacher-centered teaching methods which generally do not require teachers to have a strong knowledge about their students and TLMs.

Therefore, although it is possible for teachers to put into practice the particular lessons they have learned during INSET, they often have difficulties in applying LCM into other topics with which have not been dealt during INSET, which makes teachers to take longer to prepare a lesson with LCM.

Hence, it is necessary to take measures for encouraging teachers to work collaboratively to prepare lessons applying LCM for other topics than those they have learned during INSET, if possible, with the help of someone who has sufficient knowledge about subject content, students and TLMs. Such an occasion is expected to contribute to deepening their understanding about the students and teaching content and materials.

(c) Examinations still focus on low order thinking skills.

Another reason that many teachers do not use LMC in their daily lessons is that high-stakes tests such as national examinations still focus on low-order thinking skills, e.g., to check whether students know facts, definitions and rules.

Many countries including those in Africa aim to develop students' scientific, critical and creative thinking skills by introducing LCM (Vavrus, Thomas & Bartlett 2011). However, in some of those countries, most of the test items in high-stakes tests still measure low-order thinking skills such as remembering facts and definitions.

Since the characteristics and types of questions given in high-stakes tests such as national examinations influence what is taught and how it is taught in the classroom, it will be quite important that these examinations should include many more test times that measure higher-order thinking skills that are stipulated in the curriculum documents.

(d) Large class

Many interviewees have commented in the terminal evaluations that LCM cannot be implemented in a class with a large number of students. This issue was also selected as one of the most common challenges in the 2nd SMASE-WECSA Technical Workshop held in 2012 (SMASE-WECSA Association 2012).

In "teacher-centered" lessons where a teacher is expected to "impart" knowledge efficiently and effectively, having a large number of students in the classroom will not seriously affect the quality of teaching and learning process because the major task of students in such a lesson is to listen to the teacher carefully. On the other hand, in "learner-centered" lessons where each student needs to be given the opportunity to speak, think and carry out experiments, the number of students in a class may affect the effectiveness of the lessons. In particular, when students themselves carry out experiments, the amount of experimental apparatus available for students will affect the effectiveness of the lesson. Many teachers point out that it is difficult to implement LCM in a large class for this reason.

Therefore, when implementing LCM in a large class, some measures need to be taken, for example, to use pair-work instead of group-work, and to use demo-experiments instead of individual experiments. In addition, at the policy level, it is also necessary to formulate a policy to improve the school environments such as decreasing the number of students in a class, and increasing the number of teachers and science apparatus.

However, what is most important in LCM is not only whether the student is given the opportunities to speak, to carry out experiments by themselves, etc., but also whether the students become interested in the problem posed by the teacher, they are eager to tackle it, they struggle with it because these processes will allow students to construct knowledge based on their experience. One of the alternative solutions to the issue of large class is, for example, in the case of science, to provide the students with a learning problem/task that arouses their interests, to allow them to discuss the problem to formulate hypotheses before a teacher conducts demonstration-experiments so that they are motivated to draw conclusions from the results of the demo-experiments on their own (Itakura 1974).

(2) Major issue 2: Many of the changes observed in lesson delivery do not necessarily lead to enhancing students' thinking process.

The second issue is often mentioned by the Terminal Evaluation Teams and JICA Technical Advisors dispatched to TC Projects. They report that, although lessons delivered by the teachers who have participated in the INSET seem to have been changed, many of those changes do not seem to lead to enhancing the independent thinking of the students.

Based on their comments and observations, the following have been identified as the major reasons for this issue.

(a) Some activities are incorporated inappropriately in a lesson without considering the thinking process of students.
(b) Pedagogical content knowledge of teachers is insufficient.
(c) The foundation knowledge and skills of students are insufficient.

(a) Some activities are incorporated in a lesson inappropriately.

Some activities aiming to change a lesson from teacher-centered to learner-centered, e.g., group work, are not appropriately incorporated in some cases. For instance, group work is one of the most common activities observed in a lesson with LCM. Doing group work seems to allow each student to be engaged in learning activities more actively. However, unless each student has developed her/his own ideas/opinions before joining group work, interaction and discussion among students during group work would not be productive because, for instance, only a few students in the group lead the discussions and others may just follow them without thinking deeply. In this way, group work may deprive the students of the opportunities to be engaged in thinking process if it is not appropriately incorporated in a lesson.

In order to avoid this kind of ineffective use of group work, a lesson must be carefully designed so that group work activities are made the most of, bearing in mind the lesson objective and the context of the students. Hence, it is critically important for teachers to understand students' thinking processes. For example, in lesson planning, a teacher needs to understand what the students have already learned, what kinds of misconceptions they have, etc., so that the teacher can support his/her students to transform the misconceptions to the scientific concepts.

(b) Pedagogical content knowledge (PCK) of teachers is insufficient.

Another reason for this issue is that some teachers do not have a sufficient pedagogical content knowledge (PCK). In fact, many of the teacher training colleges in Africa, in general, teach pedagogical knowledge and subject content knowledge separately. Without PCK a teacher is inclined to teach M&S by imparting knowledge.

Hence, teachers need to learn subject content knowledge and pedagogical knowledge in an integrated manner, taking account of students' viewpoint. PCK can be learned when teachers study teaching content and teaching materials in depth, and when they reflect a lesson after they have conducted. Lesson observations and discussions to reflect the lessons conducted are considered to be an effective way to strengthen PCK. Hence, it is essential for teachers to be engaged in professional development activities which allow them to observe and discuss actual lessons in a regular-basis, for instance, through school-based INSET.

(c) The foundation knowledge and skills of students are insufficient.

In the lessons with LCM, students are expected to construct knowledge on their own based on their experience. While, at the lower primary level, students construct knowledge based mainly on their daily-life experience, at the upper primary level and above, they construct knowledge based not only on their daily-life experience, but also the knowledge they have learned in the previous grades. Hence, mastering the knowledge and skills in the previous grades, in particular, the foundation knowledge such as basic literacy and numeracy skills is highly important.

However, as shown by the results of national assessments and international assessments such as Trends in International Mathematics and Science Study (TIMSS) and the Southern and Eastern Africa Consortium for Monitoring Education Quality (SACMEQ), many children in Africa promote to upper grades without mastering the foundation knowledge and skills they are supposed to have mastered at lower grades (World Bank 2008). Consequently, some students have difficulties in learning and constructing new knowledge at upper grades because they cannot take advantage of the knowledge they are supposed to have learned in the previous grades, in particular, at the lower grades in primary level. This insufficient mastery of the previous grades prevents students from learning effectively.

(3) Possible measures for the issues and actual examples

To summarize the discussions above, measures needed to be taken to address the major issues identified from JICA's experience of supporting M&S in Africa, fall under three aspects, namely, policy, teacher and student (Table 6).

Table 6. Possible Measures for Issues and Actual Examples

Area	Measures	Example
Policy	- To revise curriculum/syllabus by selecting basic and essential content and arranging them to be appropriate for the cognitive development of learners - To revise high-stakes examinations to incorporate more items to test higher order thinking skills	- TC Project to develop the capacity of item writers to develop test items (Ethiopia)
Teacher	- To deepen the understanding of teachers about LCM - To strengthen PCK (a deeper understanding about TLMs and students)	- School-based CPD and Lesson Study (Zambia) - Action Research for teacher collaboration with the support by university (Malawi) - Error analysis (Morocco)
Student	- To reinforce the foundation knowledge and skills	- To secure study hours and conduct remedial workbooks (Niger, Senegal)

In terms of the “policy” aspect, the following measures need to be taken: to revise curriculum by selecting basic and essential content; and test items of high-stakes examinations such as national examinations need to be revised by including more items that can measure high-order thinking skills. JICA has assisted the Ethiopian government through TC project to strengthen the capacity of item writers by developing item pools. Items in the item pools are expected to be used for various examinations to be developed in Ethiopia (JICA 2015b).

In terms of the aspect of “teacher”, teachers are required to strengthen PCK to effectively apply LCM in daily lessons. In order for teachers to strengthen PCK, they need to improve subject content knowledge based on the viewpoints of pedagogy and students.

Teacher collaborative learning at school/cluster level is reported to be effective. For instance, the Project implemented in Malawi introduced Action Research for secondary M&S teachers. Many teachers had difficulty in applying LCM in daily lessons, in particular, for those topics other than those they had learned during cascading INSET. When Action Research activities are undertaken with the help of university professors, the teachers gather at the beginning of each term and developed lesson plans collaboratively for every lesson to be taught in the term. By developing all lesson plans in the term, they effectively implemented LCM (JICA 2017).

School-based Continuous Professional Development (CPD) can be also effective measures to provide teachers to strengthen PCK. For example, Zambia has implemented Lesson Study in the framework of School Program of In-service for the Term (SPRINT) so that teachers can continuously engage themselves in professional development activities at school level. They have also incorporated the element of intensive study of teaching materials, which is known as “kyozai-kenkyu” in order to strengthen PCK.

One of the ways to understand the misconceptions and thinking processes of students is to analyze mistakes made by students. For example, the Project implemented in the Kingdom of Morocco conducted diagnostic tests for 5th and 6th grade students. They analyzed the errors made by students to identify their misconceptions and thinking processes and, then, developed remedial materials to address errors that the students had made (JICA & Ministry of National Education and Professional Training, the Kingdom of Morocco 2016).

Regarding the aspect of “student”, it is critical to strengthen understanding of the foundation knowledge and mastering basic skills, in particular, basic arithmetic skills. For example, in Niger and Senegal, with the support of the communities, schools secure time outside school hours for students to do remedial work. By using the time and the remedial workbooks, students in those schools have improved basic arithmetic knowledge and skills.

Conclusion

We analyzed terminal evaluation reports for 28 technical cooperation projects implemented in 14 sub-Saharan African countries with the support of JICA. Through the comprehensive analysis, we have displayed major achievements and common challenges. We also analyzed the causes for the challenges to propose measures to be taken.

In terms of the achievements, the following three are presented: (1) INSET systems have been established; (2) Lesson delivery has improved; and (3) Students' participation in lesson improved.

On the other hand, it has been revealed that improvements observed in lesson delivery of teachers are limited in terms of quantity and quality. In terms of the quantity aspect, it is reported that the knowledge and skills that teachers have learned during INSET were not implemented in the classroom as expected because teachers feel that they cannot complete syllabus if they apply LCM in daily lessons and because the high-stakes examinations such as national examinations still focus on lower-order thinking knowledge and skills.

In terms of the quality aspect, it is identified that changes observed in lesson delivery do not necessarily lead to enhancing students' understanding because some activities are not incorporated in a lesson appropriately and because PCK of teachers and the foundation knowledge and skills of students are not sufficient.

The measures identified above can be categorized into three aspects, namely, policy, teacher, and student. In order to address the challenges mentioned above, measures need to be taken in each aspect. JICA has already started supporting projects in some of those countries to address the issues in Ethiopia, Malawi, Morocco and Zambia.

Lastly, we recommend that further research needs to be conducted to confirm our arguments in this paper. The measures proposed in Table 6 are developed from the analysis based on the results of interviews conducted and discussions made during terminal evaluations of the projects and in other opportunities such as technical workshops which brought together counterpart personnel of the projects. Hence, the causal relationships between the challenges, causes and measures are still hypotheses which need to be proved. Therefore, it is necessary to prove that those measures proposed in Table 6 are effective to address the issues identified in 4.2 when terminal evaluations are conducted for the projects, and to conduct more structured and rigorous research, e.g., quantitative research, to prove those causal relationships are true.

References

CEMASTEA (2005). *SMASSE National INSET Material for Cycle 1, ASEI-PDSI Approach*. Nairobi: CEMASTEA.

Itakura, K. (1974). Kasetsu Jikkenn Jugyo [in Japanese] (hypothesis experiment lesson), Tokyo: Kasetsu-sha.

JICA (2015a). *JICA Position Paper in Education Cooperation*. [https://www.jica.go.jp/english/our_work/thematic_issues/education/c8h0vm0000am7dbv-att/position_paper.pdf](accessed on 26th June 2017).

JICA (2015b). *Ethiopia Kyowakoku Risuka Kyoiku Assessment Noryoku Kyoka Project Jisshi Kyogi Hokokusyo* [in Japanese] (Report on implementation survey of the Project for Capacity Development for Improving Learning Achievement in Mathematics and Science Education in Ethiopia), Tokyo: JICA.

JICA (2017). *Malawi Kyowakoku Chuto Risuka Kyoiku Kyoka Project Shuryoji Hyoka Chosa Hokokusho* [in Japanese] (Terminal Evaluation Report of the Project on Project for Strengthening of Mathematics and Science in Secondary Education (SMASSE) in Malawi Phase III), Tokyo: JICA.

JICA & Federal Ministry of Education, Federal Republic of Nigeria (2009). *Minutes of Meeting between Japanese Terminal Evaluation Team and Federal Ministry of Education for and on behalf of the Federal Republic of Nigeria on Japanese Technical Cooperation for Strengthening of Mathematics and Science Education in Nigeria at the Primary Level*. Tokyo: JICA.

JICA & Ghana Education Service (2009). *Minutes of Meeting between the Japanese Evaluation Team and the Ghana Education Service on the Japanese Technical Cooperation for Project to Support the operationalization of the In-service Training Policy (INSET Project)*. Tokyo: JICA.

JICA & Ministry of Basic Education and Literacy, Burkina Faso (2010). *Minutes of Meeting between Japanese Final Evaluation Team and Authorities Concerned of the Government of Burkina Faso on Japanese Technical Cooperation for Project of Teacher Training Improvement in Science and Mathematics at the Primary Level*. Tokyo: JICA.

JICA, Ministry of Economic and Finance, Republic of Senegal & Ministry of Education, Republic of Senegal (2010). *Minutes of Meeting between Japanese Final Evaluation Team and Authorities Concerned of the Government of the Republic of Senegal on Japanese Technical Cooperation for Strengthening Mathematics, Science and Technologies Education Project*. Tokyo: JICA.

JICA & Ministry of Education, Republic of Kenya (2008). *Minutes of Meeting between the Japanese Final Evaluation Team and the Authorities concerned of the Government of the Republic of Kenya on the Japanese Technical Cooperation for the Project on Strengthening of Mathematics and Science in Secondary Education (SMASSE) Project Phase 2*. Tokyo: JICA.

JICA & Ministry of Education, Republic of Rwanda (2011). *Minutes of Meeting between*

Japanese Final Evaluation Team and Ministry of Education/Teacher Service Commission of the Republic of Rwanda on Japanese Technical Cooperation for Strengthening mathematics and Science in Secondary Education. Tokyo: JICA.

JICA & Ministry of Education, Republic of Zambia (2010). *Minutes of Meeting between Terminal Evaluations Team of Japan International Cooperation Agency and the Authorities Concerned of the Government of the Republic of Zambia on Japanese Technical Cooperation for SMASTE School Based Continuing Professional Development Project Phase II*. Tokyo: JICA.

JICA & Ministry of Education, Science and Technology, Republic of Malawi (2012). *Minutes of Meeting between the Japanese Terminal Evaluation Team and the Authorities Concerned of the Government of the Republic of Malawi on Japanese Technical Cooperation for Strengthening of Mathematics and Science in Secondary Education (SMASSE) INSET Malawi Phase II*. Tokyo: JICA.

JICA & Ministry of Education, Science, Vocational Training and Early Education, Republic of Zambia (2016). *Minutes of Meeting between Japanese Final Evaluation Team and the authorities Concerned of the Government of the Republic of Zambia on Japanese Technical Cooperation for Strengthening Teachers' Performance and Skills (STEPS) through School-based Continuing Professional Development Project*. Tokyo: JICA.

JICA & Ministry of National Education and Professional Training, the Kingdom of Morocco (2016). *Reports of error analysis on the results of the diagnostic tests of the fifth and sixth grades of the primary cycle in Mathematics and Science Activity*. Rabat: JICA.

Ottevanger, W., Akker, J. & Feiter, L. (2007). *Developing Science, Mathematics, and ICT Education in Sub-Saharan Africa: Patterns and Promising Practices*. Washington, D. C.: The World Bank.

Roth, K.J., Druker, S.L., Garnier, H.E., Lemmens, M., Chen, C., Kawanaka, T., Rasmussen, D., Trubacova, S., Okamoto, Y., Gonzales, P., Stigler, J., & Gallimore, R. (2006). *Highlights from the TIMSS 1999 Video Study of eighth-grade science teaching* (NCES 2006-17). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

SMASE-WECSA Association (2012). *Report on the 2nd SMASE-WECSA Technical Workshop*. Nairobi: SMASE-WECSA Association.

Vavrus, F., Thomas, M. & Bartlett, L. (2011). *Ensuring quality by attending to inquiry: Learner-centered pedagogy in sub-Saharan Africa*. Addis Ababa: UNESCO-IICBA.

World Bank (2008). *Curricula, Examinations, and Assessment in Secondary Education in Sub-Saharan Africa*. Washington, D. C.: World Bank.