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Assessment Pedagogical Content Knowledge (APCK): A Model for Implementing Science Classroom Assessments

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Abstract
Shulman's Pedagogical Content Knowledge (PCK), developed in the mid-1980s has undergone a number of revisions, with the aim of building upon the concept. The current paper introduces a new theoretical concept named Assessment Pedagogical Content Knowledge (APCK), for implementing formative assessment during science teaching in order to aid students' learning. The new concept, APCK, is an amalgam of knowledge that draws on how to combine assessment with pedagogy. It involves a combination of knowledge of assessment, the skills of assessment and the contents that are taught. The appropriate use of APCK inures to the benefit of students' science learning. The study uses both qualitative and quantitative approaches to show that integration of assessment with instruction has proved valuable for science learning. The feedback, which teachers give to their students during teaching are used by students to improve their learning of science. This shows that a good grasp of the concept will enable teachers to use APCK formatively when teaching science and their students will improve their science learning. Hence, APCK holds a great potential, especially for science teachers, to develop their skills of interweaving instruction with assessments to promote learning. This study then proposes that APCK of science teachers can be identified through their knowledge and practice of the inter-relationships between pedagogy and assessments.
Keywords: APCK, assessments, curriculum, formative assessment, purposes of assessment
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1. Introduction

In the science classroom each activity undertaken by teachers and students involve assessments and evaluation of the outputs of students. So at the beginning of each lesson the teacher identifies gaps in students' knowledge on particular topics through recall of previous knowledge. The teacher asks students probing questions to find out the relevance of their existing knowledge to aspects of the topic to be treated. Answers given by students at the recall stage of the lesson enable the teacher to determine a starting point of the lesson. In effect the teacher is engaged in assessing the students in order to have a soft kick-start of the lesson. Similarly, all other stages of the lesson have their purposes and these should be clearly known by an experienced teacher. Teachers with a strong APCK manoeuvre their way smoothly through each lesson using the eight components of APCK at various stages of the lesson as the activities undertaken during the lesson are evaluated. Similarly, science teachers who have strong APCK develop essential knowledge of test-taking strategies of their students and are able to give tests with appropriate levels of difficulty to their students. Experienced science teachers expect their students to acquire science process skills through the activities they perform during lessons and in the science laboratory. This implies that science teachers themselves would have acquired the science process skills earlier during their training and practice of the profession. This study used an observation table that comprised all the eight elements of APCK.

2. The Concept of Assessment Pedagogical Content Knowledge (APCK)

The concept of APCK deals with assessment literacy, which is the knowledge base of assessment. It is really an aggregation of knowledge elements depicting the teacher's internalisation of the principles underlying assessments, particularly classroom assessments or formative assessments. This study tries to clarify the knowledge bases of the various components of APCK for researchers who intend to evaluate the APCK of science teachers to be in sync with the theory. APCK is dynamic in the sense that it is intended to be changing and responding to classroom teachers' quest to organise authentic and fair assessments for their students. It is noted that whereas Shulman's 1986 PCK was about teachers' knowledge and practice of teaching methodologies, APCK is about teachers' knowledge about assessment strategies and their use in teaching to aid students' learning. It is noted that APCK is equally implicit and can only be realised through actual activities as Nind (2020) has observed about PCK. The difference lies in the fact that APCK is not about teaching to transfer subject matter knowledge to students but APCK is about the ingenuity of the science teacher to use assessments to mould the students and prepare them for their future life. A good use of APCK by the teacher empowers students to unearth their problem solving abilities.

In principle APCK comprises the knowledge of assessment issues, the dimensions of assessment practice and use of assessment for teaching. The question to ask is 'What aspects of APCK do researchers need to explore with classroom teachers?' There are two mains aspects: (1) understanding how to plan assessments, and (2) acquiring

the skills of using assessment practices as means of teaching in the classroom.

The model proposed in this study was researched in an earlier study (Amedeker, 2016) and has the following eight components as the main ingredients for science teacher engagement in practising classroom assessment or continuous assessment:

(1) knowledge of purposes of assessment, (2) knowledge of assessment of the curriculum, (3) knowledge and skills of teaching with assessments, (4) knowledge and skills of giving feedback, (5) knowledge and practice of evaluating assessment, (6) knowledge of dimensions and their alignment to tasks, (7) knowledge of characteristics of quality assessment and, (8) knowledge of types and difficulty level of tasks. A diagrammatic representation of APCK is shown in Figure 1.

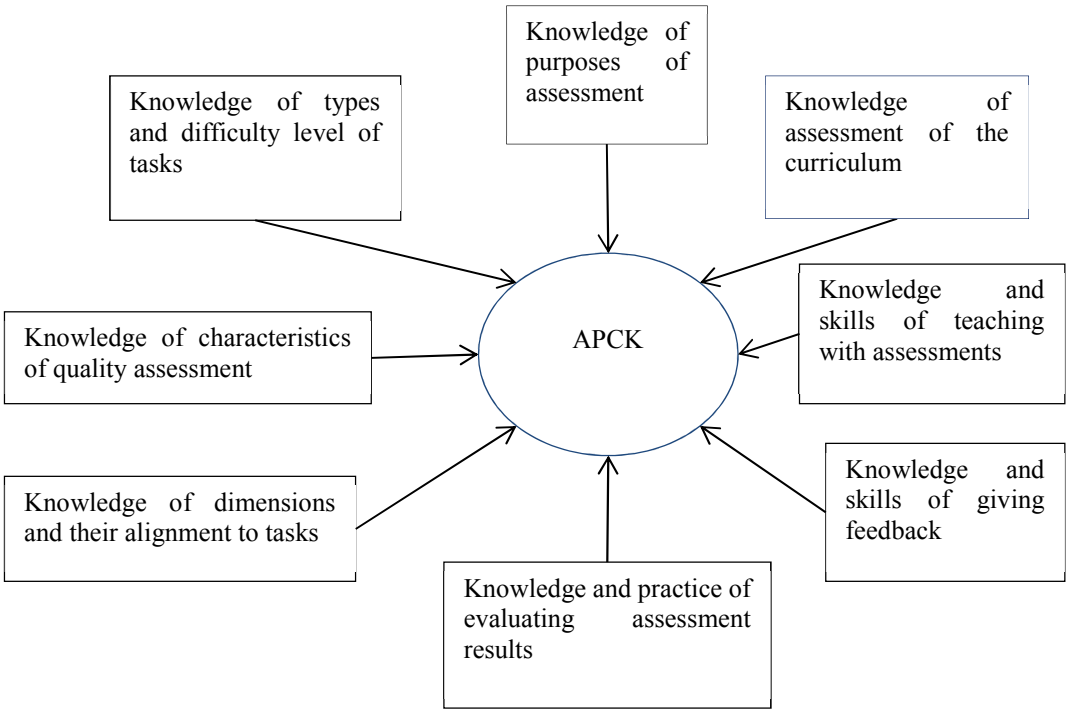

Figure 1. The components of Assessment Pedagogical Content Knowledge (APCK) (Source: Amedeker, 2016)

3. Knowledge of purposes of assessment

Assessment should have a purpose. That is to say, what one intends to do with the assessment itself as well as its outcomes Also, one should have the intention of achieving something with the assessment and its outcomes. Thus, the science teacher from the onset should understand and map out clearly the intentions behind conducting classroom assessments. However, a number of school teachers do not preconceive what they are going to do with their assessments and the results they obtain from the assessments (Amedeker, 2016). It appears to be a routine to assess after teaching but little thought is given to the purposes of assessment. Some teachers stick strictly to syllabus requirements of organising the required number of assessments for their students and these assessments end up being summative, demanding of students to regurgitate facts they have learnt. Black and Wiliam (1998b), advocated for moving into the 'black box' to unveil what happens in the 'black box'. The metaphor of 'black box' referred to the classroom and its activities in the form of assessments of the activities carried out. The authors implied that governments should not be only interested in regulations directing teachers as to how to teach and the outcomes of learners' examinations, but they should also be interested in purposes of the tests, assignments and examinations that teachers give to students. Similarly, education authorities who write the syllabus should endeavour to include the purposes for which the assessments must be done. Classroom-based assessment is qualitative, informal and performance-based (Janisch, et al., 2007). Thus, the purpose of classroom-based assessment is different from formal testing, which seeks to satisfy an external examination benchmark.

4. Knowledge of assessment of the curriculum

Shulman (1987) proposed that the teacher of a subject needed to have good knowledge of the **content** being taught. In the current article the word content has been replaced by curriculum knowledge, which implies the knowledge and skills of practice of subjects taught at school. A curriculum, thus, is broader than just the content of the subject. The curriculum requires the knowledge of teaching as well as examining subject content. Thus, the teacher must

have good knowledge of how to assess the contents stated in a syllabus in addition to teaching it. In carrying out an assessment, the teacher is faced with the task of knowing how much of the subject content that has been learnt by students and how much of the content to examine and types of skills to examine. Mikre (2010) bemoans the nature of teaching and assessment in higher education institutions, which appear to lay much emphasis on factual knowledge rather than on problem-solving skills. Each curriculum in an educational set-up spells out the types of assessment that should be aligned to each instructional strategy. Hence, how instruction is structured determines the assessment procedures that teachers should adopt for effective learning to take pace. Assessment is an integral part of the teaching and learning process. This is a type of knowledge without which the teacher may be enforcing rigid rote learning - an issue which is contrary to the constructivist approach to teaching and learning. Mikre (2010), in a review of articles in relation to the role of assessment in teaching and learning, found that most authors viewed assessment as an integral part of practice of the curriculum. For example, Akker (2003), cited in Mikre, (2010) indicated that the knowledge of the assessment of the curriculum gives the teacher means of obtaining information that would enable decision-taking on student learning. According to Mikre (2010) "the attained curriculum both the experienced and the learned are determined by assessment procedures" (p. 102). Hence, the teacher's knowledge of assessing the curriculum results from practice. With the practice of assessment of the curriculum teachers gain some experiences that would enable them to have control on using assessment in formative manner in their classrooms.

5. Knowledge and skills of teaching with assessments

Assessment Pedagogical Content Knowledge (APCK) connotes special skills of the teacher in teaching through the use of a series of assessments. In teaching, every step requires that the teacher seeks information from the students. This is in contrast to the scenario of teacher feeding students with information. The teacher serves as a role model and a leader who directs affairs of the lesson through a series of questions that will enable the students express themselves by giving the knowledge they have about the topic under discussion. While the presentation formats of lessons do vary from teacher to teacher, the constructivist approach requires that teachers would refrain from notes giving and students copying notes. The constructivist approach is laden with discourse and interactivity. Some of the activities experienced in the science classrooms are demonstrations, questioning, story-telling, gaming and other procedures that allow students' participation so as to remove boredom. Intensive questioning, especially when the teacher engages in Socratic questioning, enables students to pour out all that they know about the topic under consideration in the class. Questioning, in fact is a form of assessment. There are a number of ways that teachers may assess their students' skills during the lesson. Perhaps students may be asked to sketch, draw, label a diagram, write short answers to an oral question posed by the teacher or be called to talk about an aspect of the topic under discussion. How will teachers acquire the skills of practice listed? Teacher colleges should incorporate this in their practical training programme, especially during their school attachment sessions or internship periods. Further, regular in-service workshops to update their knowledge on use of various modes of teaching with assessment are required. As the phenomenon being advocated comprises both knowledge and skills, it is required that teachers practise the use of assessment for teaching for a period under guided supervision before they are left on their own.

6. Knowledge and skills of giving feedback

The role of assessment in improving teaching and learning is situated in the type and efficacy of the feedback given on the assessed tasks. Black and Wiliam (1998a) have indicated that formative assessment can improve the standards of achievement of students because of the feedback associated with formative assessment. Airasian (2000) has shown that information obtained from assessment may be used by teachers as well as students. While teachers may use the information to make decisions on students for their learning, students on the other hand may use information from assessment to improve their academic outputs. Thus, teachers use assessment results to make decisions about teaching and learning while students use the information to make decisions about learning. This implies that teachers of science should have an ingrained knowledge of giving feedback on assessments so that information they give about the assessment can be used as authentic feedback for improving subsequent lessons and then by students for improving learning. The main objective of a feedback is to educate the recipient on next steps to take to improve upon their learning and performance. The amount of feedback given may overburden students if they are too many. Hence, the teacher should decipher between relevant and irrelevant feedback. When students do not use the feedback due to its unappealing nature then they will not derive the benefits that feedback is expected to provide as aide for effective learning. Care must be taken to avoid ego-related feedback, which tends to evaluate the receiver rather than the task on which the receiver worked (Jug, Jiang & Bean, 2019). The authors also indicate that sometimes the crux of the feedback is missed so the recipient should be made to paraphrase the feedback to ensure clarity. Instead of thinking of a generic model of feedback that suits all learners, Ajjawi and Boud (2017) warn that feedback is socially designed and situated in the culture of the classroom operating rules or the institutional policy. Hence, teachers have to acquire good knowledge of an effective feedback, particularly

for their operation in the science classrooms. Henderson et al. (2019), in a wide-scale research conducted across some Australian universities found that design of feedback, capacity of lecturers and students, and institutional culture were factors that influenced successful feedback practices.

Thus, the skills required of the teacher are to ensure there is no ambiguity in statements written, give the feedback in a timely manner, support the learner with examples of corrections to make and give feedback which is not overly full of praises for the learner. Some of the techniques of giving feedback as suggested by Ahea, Ahea, and Rahman (2016) are using email, audio and video, screencasts, and written comments. The authors suggested that in email feedback one may send generic feedback to whole classes that are large or send individual comments to students when the class size is small. In audio and video feedback, the authors suggested that recorded voice (podcast) or a combination of voice and pictures (video) may be used to convey the messages of feedback to students. Ahea, Ahea and Rahman (2016) have also suggested screencasts as alternative means of sending feedback to students. A screencast is a technology that allows for recording of activities or actions that teachers require their students to undertake as corrections for the faults in their assignments or assigned tasks. Screencasts are computer screen based activities and they do demonstrate steps through which students would work to correct their marked works which they got wrong. While students use the technology they are also able to ask questions about their feedback. Lastly, the authors suggest written comments, which admittedly could be time-consuming for large classes. However, the advantage is that modern technology enables the teacher to re-cycle the comments written by specialised software or by standard word-processing documents.

7. Knowledge and practice of evaluating assessment

While agreeing with Gess-Newsome and Lederman (1999) that pedagogical content knowledge is fundamental knowledge base to be acquired by teachers for successful teaching this article also surmises that teaching in itself is assessment and a knowledge base of evaluating assessment outcomes. Classroom techniques begin with interrogation of students by teachers on issues related to the topic under consideration for the day's lesson. The assessment items that are used to begin the lesson fall under the terminology 'Relevant Previous Knowledge'. The evaluated assessment results for the entrance into the lesson determine the point from which the teacher should start the lesson. Hence, whether students' understandings of concepts are scientifically inclined or not becomes a starting point of the lesson. This type of assessments and their use has been known in the literature as formative assessment. A teacher's familiarity with procedures of assessment does not necessary imply ability to evaluate assessment outcomes. In formative assessment an experienced teacher evaluates the results in terms of what to remediate for academically ailing students, sustainable help to fast progressing students and what to teach next. Though Schulman's 1987 conception of PCK included classroom techniques, it only laid emphasis on generic classroom practices such as a teacher's leadership roles in the teaching and learning process without emphasis on evaluation of assessment outcomes. Evaluation of assessment results is done through critical examination of students' responses to oral questions, written tests and statistical analysis of responses provided by students. According to Edwards (2013) assessment of science learning is complex. Hence science teachers in their bid to teach well to the understanding of their students require special skills to teach in addition to skills of assessing their students. Thus, Edwards (2013) proposes evidence of learning as one of the major areas of focus during teaching. To ensure that the teacher is able to determine the occurrence of learning then the teacher needs to acquire good knowledge and practice of evaluating assessment outcomes. The evaluation of assessment results implies that the teacher seeks to make a decision on the students' future performance. This calls for careful observation of students during class activities, tests and quizzes or seminar presentations. After such observations the teacher will be able to make useful decisions with the assessment results. Hence, in presenting termly reports on students to parents the teacher must have the skills of interpreting the learning outcomes of students to parents. The traditional methods of schools presenting only marks in each one of the subjects that the student has offered is getting outmoded as the school system is becoming more complex and parents and guardians are getting more worried about the future of their wards.

8. Knowledge of dimensions and their alignment to tasks

The Ministry of Education (MoE) (2010) has categorised learning dimensions as profile dimensions in the Ghanaian Integrated Science Syllabus and defined a dimension as "a psychological unit for describing a particular learning behaviour" (p. viii). At the level of the senior high school, three dimensions of teaching and learning have been recommended for teachers and students. These are "Remembering and Understanding, Applying Knowledge and, Practical and Experimental Skills" (MoE, 2010, p. viii). The dimensions appear in all levels of education for teaching all school subjects and have been weighted differently for each level of education. Hence, teachers of science need to have good knowledge of the dimensions of learning and teaching that are appropriate to the level at which they are teaching science. In a research into teacher education, Nielsen and Lund (2020) proposed three ways for professional handling of the dimensions of teaching and learning. These were ways of handling knowledge, types of knowledge available and knowledge concerning the content that is taught. These three

dimensions require of the science teacher to develop the skills of creating different types of knowledge and demonstrate these through researching issues concerning the profession as well as knowledge of the taught content.

However, since APCK is about using assessment during teaching to help students learn effectively, the assessment tasks must be aligned to the dimensions of learning. This implies that test items or questions to be used during teaching should incorporate the various levels of dimensions consistent with the level at which teaching is being done. For example, in teaching Integrated Science at the senior high school level three dimensions have been stated as policy requirements in the Ghanaian science syllabus. Questions used during teaching are, thus, to incorporate items on remembering and understanding, application of knowledge and experimentation. It should be noted that a combination of the different types of dimensions (profile dimensions) is dependent on the level at which teaching is done. At higher levels of teaching, like senior high school and tertiary levels, one introduces more complex profile dimensions like synthesis, analysis, evaluation and creativity. The focus of APCK is how to handle the various types of dimensions at each level of education and how to align them o tasks in the classroom. In as much as the level of dimension should not be above the level of performance of students, it is advisable that science teachers use their ingenuity to ensure fairness and equity in the application of profile dimensions in the tasks they set for students. The rationale for each dimension is to stimulate learning in the science students. The science teacher is, therefore, expected to develop the skills of consciousness, construction and execution of the profile dimensions at the appropriate levels of teaching. An experienced science is aware that assessment is embedded in the teaching and learning processes. The correct implementation of assessments during teaching enables the achievement of curriculum objectives when the questioning or assessment items used are appropriate. According to Mikre (2010) the quality of curriculum practice and learning assessments are very important as they affect the acquisition of transferrable skills that students send to the workplace.

9. Knowledge of characteristics of quality assessment

The characteristics of classroom assessments are varied and difficult to attain by many teachers due to the varied behaviours exhibited by students of diverse backgrounds in the class. It is, therefore, important to create a classroom culture the enables the teacher to achieve entire student participation. In order to involve every student Shepard (2000) suggests that " to accomplish the kind of transformation envisioned, we have not only to make assessment more informative, more insightfully tied to learning steps, but at the same time we must change the social meaning of evaluation" (p. 10). Quality classroom assessment requires that it is integrated into the teaching process, occurring at all stages of teaching. The classroom assessment should aim at promoting learning. Assessment for learning, therefore, ties in with Vygotsky's theory of zone of proximal development, which emphasises difference between a learner's capabilities while performing a task independently and when collaborating with others on a task. In a classroom assessment the content or topic taught and the procedure of presentation of the lesson is very important for students' learning. Thus, the quality assessment is obtained from items or questions used during the teaching processes and the way the test items were interwoven with the instruction. In a study by Ibarra–Siaz, Rodriguez-Gomez and Boud (2021), students noted that the characteristics of assessment that enabled them to learn very well were feedback, participation and, empowerment and self-regulation. This finding implies that when students are given chance to participate in various class activities they feel they are acquiring science process skills and hence being empowered. Students tend to appreciate instant feedback that enables them to amend their ways of performing tasks. A science teacher with a good APCK is the one who has good knowledge of characteristics of quality assessment such as giving feedback and also goes to the extent of empowering students to take control of their learning. Just as PCK is a blend of knowledge and content that is taught, similarly APCK is a blend of knowledge of quality assessment tasks and the assessment practices. The frequency or otherwise of assessment practices determines its quality.

10. Knowledge of types and difficulty level of tasks

Most teachers, especially, novice ones find it difficult to determine the different types of assessments tasks that may be used in the science classroom. Teachers who are experienced may have great insights into how much good assessment tasks influence students' learning during the lesson. APCK is also about teachers' knowledge about the influence of the nature of tasks and their difficulty levels on students' learning in the classroom. Classroom assessment tasks may include anecdotal presentations, dialogues, portfolios, questions and answers and observation checklists for recording activities. Teachers who have good knowledge of assessments are able to use the correct strategies to help students' learning. In a technologically rich classroom, videos and voice recording may form part of the assessment tools. A science teacher with good knowledge in assessment will make a distinction between assessment of knowledge and assessment of practice. In science teaching these two types of assessments may be called traditional tests and alternative assessments, respectively. Alternative assessments may include science practical work or demonstration, portfolios and class presentations, which enable students to display special skills learnt. For example, students may be asked to demonstrate newly acquired skills such as titration or measurement in the laboratory. Thus, alternative assessment is also called authentic assessment or

performance test. Students participating in a course noted that authentic assessment enabled them to take responsibility for their own learning and develop positive attitude to studying (Janisch, Liu & Akrofi, 2007).

11. Empirical Evidence for APCK

In order to test the operation ability of the concept of APCK for use in the science classroom, data from earlier work (Amedeker, 2016) is displayed in Table 1 of Appendix A. Two professional development workshops were organised for 56 science teachers of basic schools (junior high schools) in an education district in Ghana. During the first workshop the science teachers' knowledge and practice of classroom assessment and, integration of assessment with instruction were explored through a questionnaire. The teachers were then instructed with a Manual prepared on the APCK skills for integrating instruction with assessment. The Manual was developed with the following 10 APCK skills:

Skill 1 – Recognising quality continuous assessment tasks in science
Skill 2 – Designing good continuous assessment tasks in science
Skill 3 – Developing good assessment criteria (marking scheme)
Skill 4 – Writing quality feedback on students' continuous assessment tasks
Skill 5 – Using questions to diagnose students' learning difficulties
Skill 6 – Developing good homework tasks that engage students in learning
Skill 7 – Determining the appropriate tasks needed to assess each dimension of learning
Skill 8 – Assessing students' group work
Skill 9 – Using feedback to help students' learning of science
Skill 10 – Maintaining consistency between curriculum objectives, what is taught and assessed

Another questionnaire was used to survey the teachers' skills of APCK at the end of the first workshop. They were allowed to take their Manuals back to school for a three-month long practice of APCK skills.

11.1. School visits

During the practice period the researcher visited each school to provide support for the teachers on their practice of APCK skills. The visits were also used to check on how the teachers were implementing the APCK concept. Some of the teachers indicated their problems with the practice of the concept and the researcher aided them to solve the identified problems.

Some of the teachers' challenges of implementing APCK

Some of the concerns raised by the teachers were found in the skills they indicated they were not confident in performing. These were 'Assessing students' group work' as they complained that their class sizes were large and space was hardly available to group students. Then 'Maintaining consistency between curriculum objectives, what they taught and assessed' as they had had no training in analysing the curriculum. Thirdly the teachers indicated they were not confident with 'Using questions to diagnose students' learning difficulties'. The other skills they felt they did not perform well were 'Recognising quality continuous assessment tasks in science' and 'Designing good continuous assessment tasks in science'

A second workshop was organised for the teachers after the three-month long period of practice. At this workshop the researcher reviewed the Manual with the teachers and asked them to express their perceptions about their practices. A number of the teachers indicated that they were able to write good marking rubrics for their test items and the questions they used during teaching. They expressed great hope of effectively integrating their instruction with assessments in their future lessons. They felt they had acquired skills that would improve their science teaching.

11.2. Results

11.2.1. The teachers' confidence of practising APCK skills

At the end of the second workshop the teachers were served with a questionnaire that required them to rate their self-efficacy in the practice of the 10 APCK skills.

Analysis of the self-efficacy ratings

The teachers rated themselves on a five-point scale rating, of which the mark allocations were: Greatly effective (5), Very effective (4), Effective (3). Ineffective (2), and Very Ineffective (1). During the analysis of data, the five scales were combined to obtain three scales of: 'Greatly effective/Very effective; Effective; and Ineffective/Very ineffective'. The allotted marks were added and their means calculated and the esults compiled in Table 1 of Appendix A. The teachers expressed high self-efficacies of performance in five of the 10 APCK skills, which are listed below. They were confident that the five skills shown were easier for them to perform and their mean self-efficacies for each of the five skills were greater than the overall mean self-efficacy of 3.90. This implies that the teachers were able to develop tasks, wrote good marking schemes and gave good feedback, which they believed helped their students to learn. The skills were:

(i) Skill 3: Developing assessment criteria (marking scheme) (Mean = 4.18.)

(ii) Skill 9: Using feedback to help students' learning of science (Mean = 4.05)
(iii) Skill 4: Writing quality feedback on students' students' continuous assessment tasks (Mean = 4.00)
(iv) Skill 7: Determining the appropriate tasks needed to assess each dimension of learning (Mean = 3.93)
(v) Skill 6: Developing homework tasks that engage students in learning (Mean = 3.91).

Comparison of the four self-efficacy rating occasions

A comparison was made of the elf-efficacy ratings of the teachers for the Pre-Intervention, Post-workshop 1, Pre-Workshop 2 and Post-Workshop 2 sessions. This was to enable the researcher to determine the progress of the science teachers in implementing the APCK skills. The mean self-efficacy scores for the Post-Workshop 2, shown in Table 1, indicated that the first two APCK skills which the teachers were confident in were skills 3 and 9 which had means of 4.18 and 4.05, respectively. Considering that these self-efficacy ratings were out of 5 points, it is seen that the teachers were 83.6 % and 81.0 % confident, respectively, of their practices of skills 3 and 9.

Skills that the teachers expressed confidence about

(i) Skill 3: Developing assessment criteria (marking scheme) (Mean = 4.18.)
(ii) Skill 9: Using feedback to help students' learning of science (Mean = 4.05)
(iii) Skill 4: Writing quality feedback on students' students' continuous assessment tasks (Mean = 4.00)
(iv) Skill 7: Determining the appropriate tasks needed to assess each dimension of learning (Mean = 3.93)
(v) Skill 6: Developing homework tasks that engage students in learning (Mean = 3.91).

Skills that the teachers expressed less confidence in

(i) Skill 2: Designing good continuous assessment tasks in science (Mean = 3.88)
(ii) Skill 1: Recognising quality continuous assessment tasks in science (Mean = 3.86)
(iii) Skill 5: Using questions to diagnose students' learning difficulties (Mean = 3.84)
(iv) Skill 10: Maintaining consistency between curriculum objectives, what they and assess (Mean = 3.79)
(v) Skill 8: Assessing students' group work (Mean = 3.57)

Thus, the standard set by this paper was that if the overall mean performance in a skill fell below 3.90 then the teachers needed to rally more effort to improve upon their performance. It may be said that an overall performance of 3.90 out of 5.00 is good. Though the science teachers had acquired new assessment skills from the workshops and practised them in their various schools they still felt they could still improve upon their skills.

12. Conclusion

The empirical evidence in this study has shown that none of the APCK skills practised by the science teacher fell below a mean score of 3.57 out of a maximum scale of 5.00, which is about 71.4 %. The result is an indication of the satisfaction with which the teachers acquired and practised the APCK skills. Hence, it is essential to include APCK in the professional development workshops organised for in-service as well pre-service teachers. This will enable the teachers to distinguish between the knowledge and practice of assessment *for learning* and assessment *of learning*. The fact that classroom assessments should be conducted regularly is an indication of good teaching and effective learning. Further, it is necessary to teach APCK to pre-service teachers because of its potential benefits to equip them with the knowledge and understanding of the APCK concept. However, the acquisition of the skills of APCK demands regular practice and it remains a classroom experience, which cannot be obtained through theoretical teacher-training coursework.

13. Implications for Teaching and learning

Assessment Pedagogical Content Knowledge (APCK), as a body of knowledge has shown that science teachers who practised it were satisfied that their students were engaged in meaningful learning. Evidence from inspection of students' exercise books indicated that they made use of teachers' feedback to improve their understanding of science concepts. Teaching with APCK at the back of their minds, teachers' lesson notes preparation will improve as they will think of the assessment components to include in the lessons. APCK is a concept that draws deeply on teachers' imagination and innovation for each lesson they teach and when teachers practise APCK well their lessons will be enriched with intermittent assessment tasks.

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Appendix A

Table 1. Teacher ratings of self-efficacy with various assessment practices on four different occasions (n = 56)

	Pre-Intervention				Post-Workshop 1				Pre-Workshop 2				Post-Workshop 2			
Skills	Greatly effective/ V. effective	Effective	V. ineffective/ Ineffective	Mean	Greatly effective/ V. effective	Effective	V. ineffective/ Ineffective	Mean	Greatly effective/ V. effective	Effective	V. ineffective/ ineffective	Mean	Greatly effective/ V. effective	Effective	V. ineffective/ ineffective	Mean
Skill 3	34 (60.7)	18 (32.1)	4 (7.1)	3.66	42 (76.3)	12 (21.8)	1 (1.8)	4.07	41 (73.2)	15 (26.8)	0 (0.0)	4.02	46 (82.1)	10 (17.9)	0 (0.0)	4.18
Skill 9	30 (53.6)	22 (39.3)	4 (7.1)	3.63	42 (77.7)	11 (20.4)	1 (1.9)	4.07	35 (62.5)	19 (33.9)	2 (3.6)	3.86	44 (78.6)	12 (21.4)	0 (0.0)	4.05
Skill 4	30 (55.6)	17 (31.5)	7 (13.0)	3.52	43 (78.2)	10 (18.2)	2 (3.6)	4.02	43 (76.8)	10 (17.9)	3 (5.4)	4.00	42 (75.0)	11 (19.6)	3 (5.4)	4.00
Skill 7	22 (39.3)	25 (44.6)	9 (16.1)	3.29	41 (74.6)	12 (21.8)	2 (3.6)	3.96	27 (48.2)	24 (42.9)	5 (8.9)	3.48	41 (73.2)	15 (26.8)	0 (0.0)	3.93
Skill 6	36 (64.2)	18 (32.1)	2 (3.6)	3.80	39 (72.2)	13 (24.1)	2 (3.8)	4.00	32 (57.2)	23 (41.1)	1 (1.8)	3.57	40 (71.4)	16 (28.6)	0 (0.0)	3.91
Skill 2	22 (40.0)	28 (50.9)	5 (9.1)	3.36	43 (78.1)	11 (20.0)	1 (1.8)	4.09	38 (67.8)	18 (32.1)	0 (0.0)	3.77	40 (71.5)	16 (28.6)	0 (0.0)	3.88
Skill 1	14 (26.5)	34 (64.2)	5 (9.5)	3.19	35 (63.6)	18 (32.7)	2 (3.6)	3.78	41 (73.3)	15 (26.8)	0 (0.0)	3.91	40 (71.4)	16 (28.6)	0 (0.0)	3.86
Skill 5	30 (55.5)	21 (38.9)	3 (5.6)	3.65	39 (72.2)	14 (25.9)	1 (1.9)	3.94	31 (55.3)	25 (44.6)	0 (0.0)	3.77	35 (62.5)	20 (35.7)	1 (1.8)	3.84
Skill 10	30 (53.5)	24 (42.9)	2 (3.6)	3.59	38 (69.1)	16 (29.1)	1 (1.8)	3.95	38 (67.8)	18 (32.1)	0 (0.0)	3.89	34 (60.8)	22 (39.3)	0 (0.0)	3.79
Skill 8	23 (41.9)	22 (40.0)	10 (18.1)	3.25	33 (60.0)	19 (34.5)	3 (5.4)	3.69	29 (51.8)	23 (41.1)	4 (7.1)	3.55	26 (46.4)	28 (50.0)	2 (3.6)	3.57
Overall mean				3.49				3.96				3.78				3.90

Note. Figures in brackets are percentages. Some few teachers did not respond to all items (Source: Author, 2016)

Appendix B

The 10 skills and knowledge of APCK:

Skill 1 - Recognising quality continuous assessment tasks in science
Skill 2 – Designing good continuous assessment tasks in science
Skill 3 – Developing good assessment criteria (marking scheme)
Skill 4 – Writing quality feedback on students' continuous assessment tasks
Skill 5 – Using questions to diagnose students' learning difficulties
Skill 6 – Developing good homework tasks that engage students in learning
Skill 7 – Determining the appropriate tasks needed to assess each dimension of learning
Skill 8 – Assessing students' group work
Skill 9 – Using feedback to help students' learning of science
Skill 10 – Maintaining consistency between curriculum objective, what I teach and what I assess