Scaffolding Formative Assessment Practices Using a Learning Progression for the Particle Model of Matter

Umesh Ramnarain[a] and Manzini Hlatshwayo[a]

Corresponding author: Umesh Ramnarain (uramnarain@uj.ac.za)

[a]Department of Mathematics, Science and Technology Education, University of Johannesburg, Auckland Park, 2006, South Africa

Abstract

Incorporating formative assessment strategies in classroom instructional practices is challenging for teachers. This study investigates how a learning progression for the particle model of matter can be used to scaffold teachers in enacting formative assessment practices in their classrooms. Lesson observations of four teachers who participated in the study were conducted to capture teachers' classroom practices. Also, semi-structured interviews were conducted with the teachers to determine their views and understandings of formative assessment, and to assess their views on using a learning progression to support the design of formative assessment. Thereafter, teachers participated in a professional development programme based on the Formative Assessment Design Cycle (FADC) that was aimed at empowering teachers with knowledge and skills to design and implement formative strategies in classrooms. Lesson observations were also conducted post-intervention to determine changes in teachers' classroom formative assessment practices. The study found that teachers had limited understanding of formative assessment, had no knowledge of how a learning progression can be used to support design of formative assessment practices. While the teachers' knowledge of formative assessment and their formative assessment practices improved after engaging in professional teacher development programme, there were still gaps in their knowledge and practices.

Keywords: formative assessment, learning progression, formative assessment design cycle

Introduction

The trend in the poor science performance of South African learners is reflected in their results in the school leaving National Senior Certificate Examination (NSC) and in international assessments such as Trends in Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) (Reddy et al., 2020). The teaching strategy adopted by teachers in classrooms has been isolated as a significant factor that contributes to learners struggling to grasp concepts in science (Mabena, Mokgosi & Ramapela, 2021). A paradigmatic shift in learning towards individual learners constructing understanding of knowledge necessitates that teachers adopt approaches that personalise the learning of their learners and understand that learners construct knowledge at different rates (O'Neill, 2013). Such as approach is encapsulated in formative assessment practices that place the learner at the centre of the teaching and learning activity. This approach and is aimed at supporting learners to be active in the learning process by facilitating them in constructing understanding of knowledge (Gengle, Abel, & Mohammed, 2017).

Formative assessment is a learner-centred approach that focuses instruction on the needs, preferences, and interest of the individual learner in the classroom (Gengle et al., 2017). Formative assessment as a teaching strategy holds the promise that it can afford every learner with an opportunity to actively participate in their learning (Lim, Lee & Lee, 2023), and to

improve their performances (Bennett, 2011). When using formative assessment, teachers employ a range of pedagogies to accommodate the different needs of learners (Ahmed & Winberg, 2024; O'Neill, 2013). Formative assessment encourages learners to take greater responsibility for their own learning and inspires a love of learning (Bennett, 2011). The use of formative assessment acknowledges the fact that learners learn best when provided with opportunities to learn not only from the teacher but also from other learners and resources outside the classroom (O'Neill, 2013). Furtak and Ruiz-Primo (2008) asserts that for teachers' instruction to be successful in helping learners to achieve their learning goals, teachers must employ formative assessment where they assess their learners while learning is in progress to gain information about learners developing an understanding to adapt the instruction.

Learning progressions as a scaffold for formative assessment

Learning progressions are defined as descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate over a broad span of time (Duschl, 2019). Learning progressions have the potential to help teachers gain clarity on learners' learning pathways and milestones they reach on their way to achieve set standards (Duschl, 2019). They help to describe how the subject content is organised from least to most complex relative to the ways learners learn (Mohan, Chen & Anderson, 2009). Learning progressions are promising tools in designing assessment, and improving pedagogy (Sevian & Talanquer, 2014). For the learners to achieve the set standards, teaching should involve monitoring learners' progress and intervening on a timely basis (Duschl, 2019). Formative assessment supported by learning progressions can provide information that is easily interpreted for teachers to make informed and precise decisions about learner needs and how to respond (Furtak et al., 2010). Thus, learning progressions might serve as scaffolds for teachers' design of formative assessment tasks in their classrooms, and as a tool for understanding changes in learner learning (Bennett, 2011).

The particle model of matter is critical in chemistry education because it provides a reasonable explanation for the behaviour of matter and can be used to explain the properties of solids, liquids, and gases. It offers a plausible explanation on what happens when matter changes state. Since the knowledge area of the particle model of matter cuts across the three grades (8 to 10) of the South African school science curriculum, it presents a suitable topic to be used to assess the impact of using learning progression to support enactment of formative assessment. A learning progression for the particle model of matter is attached as supplementary material.

The capacity of teachers to use a learning progression to enact formative assessment in the classroom can be improved through a well-structured and content-specific continuing teacher professional development programme (Rosenberg, Nsubuga & Burt, 2009). Hence the aim of this study is to investigate how a learning progression for the particle model of matter can be used to support teachers in enacting classroom formative assessment practices.

The following research questions guided the study:

1. What are the views and understandings of grade 8 and 9 Natural Sciences and grade 10 Physical Sciences teachers on formative assessment?
2. What are existing formative assessment practices of grade 8 and 9 Natural Sciences and grade 10 Physical Sciences teachers?

3. How do the grade 8 and 9 Natural Sciences and grade 10 Physical Sciences teachers' views and understandings of formative assessment change after participation in the Formative Assessment Design Cycle (FADC)?
4. How do the grade 8 and 9 Natural Sciences and grade 10 Physical Sciences teachers formative assessment practices change after participation in the Formative Assessment Design Cycle?

Formative Assessment Design Cycle (FADC) model

The Formative Assessment Design Cycle (FADC) model, which is a five-step approach for teacher professional development (Furtak, Kiemer, & Swanson, 2015), was used to support teachers' development of formative assessment activities (Figure 1).

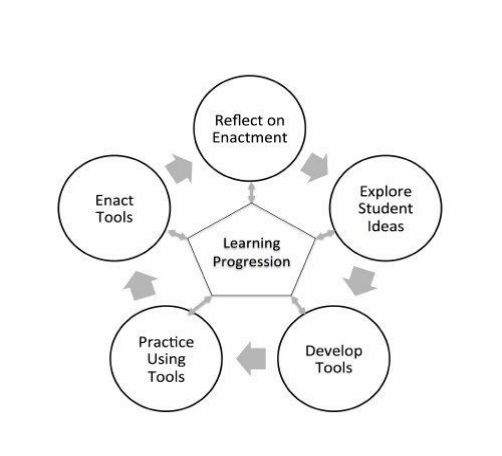

Figure 1 Formative Assessment Design Cycle
Source: Furtak et al. (2015)

The cycle begins by guiding teachers to ***explore learner ideas*** as well as their own understanding of the particle model of matter. Typical learner responses on classroom activities are used to facilitate the discussion. The focus is not on judging whether the learners' ideas are correct or not, but on determining the level of development of the learners' ideas on the learning progression. The second stage of the development cycle involves assisting teachers to identify areas in which they will focus and ***develop tools*** to scaffold learners towards a well-articulated explanation of the particle model of matter. The development of tools is then followed by the stage where the teachers ***practice using the tools***. This involves rehearsing using the formative assessments, categorizing samples of learner responses, and anticipating learner responses and feedback they might provide to the learners to help them move to more sophisticated levels of understanding (Furtak et al, 2010). The fourth stage of the cycle focuses on encouraging teachers to ***enact the tools*** during their instructional activities in classrooms. In this stage, teachers are encouraged to apply the tools and the skills acquired during Professional Learning Communitty (PLC) meetings to their classrooms. For feedback and discussions in the next PLC meetings, teachers also monitor and record the appropriatness and effectivenes of the formative assessment activities. The final stage of the cycle focuses on supporting teachers to ***reflect on enactment***. Here, teachers sharing their classroom experiences and are given feedback on the relevancy and effectivenes of the collectively developed formative assessment activities.

Methodology

A qualitative case study design was employed to gain in-depth insight into how teachers engage with a learning progression to support formative assessment practices in their classrooms (Yin, 2018). The case for this study comprised four science teachers who were teaching the particle model of matter.

Sampling

Convenience sampling was used to select three rural schools in an education circuit of Mpumalanga Province in South Africa. An education circuit in South Africa is an administrative subdivision within a provincial education district and is comprised of 15 to 30 schools. All three schools are classified as quantile 1 (no fee schools). They are poorly resourced and within an area that has a high rate of unemployment. Four teachers who each taught grades 8 and 9 Natural Sciences and grade 10 Physical Sciences participated in the study. The four teachers consisted of two males and two females and had teaching experiences ranging from two years to 17 years. Pseudonyms are used to protect the confidentiality of the participants. All the teachers were professionally qualified as teachers with one teacher having a secondary Teacher Diploma (STD obtained from a Teacher College (Ms Mdlalose), two teachers having a Bachelor of Education (B.Ed) qualification obtained from universities (Mr Luruli and Mr Sithole) and one teacher having a Bachelor of Science (B.Sc) and a Post-Graduate Certificate in Education (PGCE) obtained from a university (Ms Nzimande).

Teacher workshops

Teacher professional development adopted a hybrid approach that was a combination of face-to-face and virtual workshops. The workshops were structured according to the stages of the FADC model already described. In order to orientate teachers towards the FADC model, they were guided in the analysis of videos of formative assessment practices that were carefully sourced from various platforms. Thereafter, they were supported in enacting the stages of FADC for the particle model of matter. The study focused on the integration of the formative assessment strategies, derived from Black and Wiliam (2009) and operationalised using Oswalt's (2013) observation protocol. For example, in clarifying and sharing learning intentions and criteria for success, teachers were guided to make learning objectives explicit and co-construct criteria with learners to support their understanding of learning goals. In eliciting evidence of student understanding, teachers were guided in using strategies such as probing questions, concept cartoons, annotated diagrams, and real-life application questions. The teachers were supported in providing feedback to learners that was formative and less evaluative in order to move learners forward in their conceptual understanding. The teachers were also supported in how to enact learners peer- and self-assessment, and on-the-fly assessment in their classrooms.

Ethics approval

Ethics approval was obtained from ethical clearance committee of the university where the researchers are situated. The ethical approval certificate is uploaded in supplementary materials.

Data collection and analysis

Semi-structured interviews were conducted with the teachers before and after they participated in professional teacher development (FADC model) to determine their views and knowledge of formative assessment, and also on learning progression to support the design of formative assessment. Similarly, classroom lesson observations were conducted before and after teachers

participated in the professional teacher development to capture teachers' existing classroom practices and to determine how teachers' formative assessment practices changed after participation in the professional teacher development.

Teachers' interviews were video recorded, transcribed, and coded using the Saldana coding (Saldana, 2013). The codes were grouped into categories which were then used to generate themes that characterised teachers' views and understanding of formative assessment and the use of learning progressions to support design of formative assessment (Furtak et al., 2015). A codebook was developed and subsequently shared with a second researcher, who independently applied it to code the interview data. The codebook is attached as supplementary material. To evaluate inter-rater reliability between the primary researcher and the second coder, Cohen's kappa coefficient was calculated (Miles & Huberman, 1994). A value of 0.81 indicated substantial agreement between the codes. Differences in coding were then resolved through a discussion.

Lessons observed were video-recorded, transcribed and analysed using the formative lesson observation protocol (Oswalt, 2013). This protocol evaluates the prevalence of the six elements of formative assessment in the teacher's classroom practices and allocates a rating of 1 to 5 to each of the elements. The six elements of formative assessment are: classroom climate; learning objectives/goals; monitoring learning; giving feedback; self-assessment; and peer assessment (Oswalt, 2013). Classroom climate assesses the effort made by teachers to create a classroom climate that supports effective teaching and learning. It also assesses the level of collaboration between learners to create a classroom climate that support effective teaching and learning. The learning objectives or goals element evaluates whether teachers use learning progressions to design learning objectives or goals and whether the learning objectives or goals are shared with the learners. Monitoring learning evaluates teachers' efforts to monitor learner learning on an ongoing basis (minute-to-minute and day-to-day). The giving feedback element evaluates whether the teacher gives meaningful and accurate feedback immediately following formal or informal evaluation of learner progress. The element on self-assessment evaluates whether the teacher gives learners opportunities to use self-regulatory competencies and whether the teacher makes an effort to develop self-monitoring competencies in learners. The element on peer assessment evaluates whether the teacher gives learners opportunities to engage in peer-monitoring and whether the teacher utilises the results of peer activities to strengthen ongoing assessment of learner learning. Content validity of the observation protocol was established in earlier studies through expert review and iterative refinement to ensure the protocol captures key dimensions of formative assessment already described. The lesson observation protocol is attached as supplementary material.

Results

The results are now presented to address the research questions.

Teachers' views and understanding of formative assessment: pre-intervention

The teachers were first asked to express their opinion on the importance of teaching the particle model of matter to grades 8, 9 and 10 learners. They recognised the value of including the particle model of matter in the curriculum for grades 8 and 9 Natural Sciences and grade 10 Physical Sciences. The reasons cited ranged from general scientific literacy and understanding of natural phenomena. This was evident from Ms Mdlalose's response as indicated in the

interview except: "It does help because the changes in each state of matter helps them to know more about Natural Sciences and Physical Sciences."

The importance of having the particle model of matter as part of the curriculum was also confirmed by Mr Luruli. Here he suggested the topic is fundamental to learning of other knowledge in higher grades.

> *Because in grade 10 there is also the particle model of matter so if they have the basics from grade 8 and 9 they will be able to apply those basics when they reach grade 10, if they happen to choose Physical Sciences.*

When teachers were asked about their preferred teaching strategies for teaching the particle model of matter, they mentioned demonstration and modelling as their pedagogical strategies of choice. However, owing to a lack of physical resources, they were limited to drawing shapes of particles on the chalkboard and using these representations in their explanations. This is reflected in the following comment by Ms Mdlalose: "We cannot demonstrate so we do the theory part, especially on the chalkboard. You draw for them."

The teachers acknowledged that showing learners models would have had great impact on the learners understanding of the particle model of matter if they had access to appropriate resources. This view is reflected in the following comment by Mr Sithole: "Perhaps if we had a model they could then see that this thing should be like."

When asked about their understanding of formative assessment, the teachers displayed a lack of knowledge and understanding of formative assessment. The teachers' understanding of formative assessment can be summarised by the comment made by Ms Luruli when she pronounced "I'll admit that I don't have too much information about that one." As evidenced in the comment below, only one teacher, Mr Sithole, displayed a partial understanding of formative assessment.

> *I think it can help us in this way; to make these learners understand these particles, if indeed we are assessing them step-by-step as a requirement of formative assessment we will detect as early as possible that these learners are now dislocated, they are not understanding this.*

Mr Sithole's view is regarded as partial understanding of formative assessment because while he understood that formative assessment is an assessment for learning, he still displayed limited knowledge on the processes that constitutes formative assessment. He viewed formative assessment as an organized step-by-step process, when in fact is an iterative process that is driven by the discourse between the teacher and the learner (Heritage, 2007). It can therefore be concluded that the teachers displayed limited knowledge and understanding of formative assessment as a teaching strategy.

Teachers' views on using learning progression to support the design of formative assessment

When teachers were asked their views on the use of learning progressions to support the design of formative assessment, they showed a complete lack of understanding of a learning progression. They indicated that they had not heard of the construct. For example, Ms Nzimande stated: "I am sorry sir I don't think I have come across that." Ms Mdlalose displayed a similar lack of understanding, and in fact associated it with a particular discipline in science: "Maybe that is a concept in Physical Sciences."

The teachers were then shown a learning progression for the particle model of matter. The learning progression was briefly explained to the teachers during the interview. After showing

and explaining the particle model of matter to the teachers, to a certain extent they recognised the value of a learning progression in science teaching and learning. For example, Ms Luruli had the following to say about how she would use the learning progression in class if she knew about it:

> *I would make my outcome based on the category to check if they understand. For example, we have a level which is zero; no response right? To check that topic; did they respond, or they didn't respond. I check based on this, and then coming to the descriptive, that is where I will know that 'Okay, my learners are at this stage,' so I have to come up with an outcome that we'll have at the end of the lesson.*

Mr Sithole saw value in the learning progression by referring to how it would enable him to identify the current level of learner understanding. He proclaimed:

> *When I look at it, rather than answering your question, it came to me to say, "How far are my learners here?" because I'll just peruse this much quicker. How far are my learners? Can they, at just level three combine both particles and continuous ideas?*

As reflected below, Ms Mdlalose responded in a similar manner as Mr Sithole.

> *With this information that we have it will be much easier to compile or to prepare a lesson based on the particle model of matter because now you will be having knowledge of how the learners are able to comprehend the information. You know the levels that some learners are on this level and others are on this level so as a result it would be easy to know how you can construct your lesson.*

Mr Luruli elaborated on how a learning progression would support his lesson planning by saying:

> *This can help in designing a lesson in such a way that you will know that you have to start with a basic thing so that the learners as we continue with the topic, they will reach each stage and understand that one.*

The teachers intially had a naïve understanding about a learning progression. However, when shown and taken through a learning progression, they were able to identify positive aspects of knowing and possibly using a learning progression. Ms Luruli was able to determine that learning progression would be useful to develop learning outcomes. Similarly, Mr Sithole and Ms Mdlalose resolved that learning progression would enable them to identify current levels of learners' knowledge. Lastly, Mr Luruli envisioned that a learning progression would be useful for designing an effective lesson.

Teachers' existing classroom practices

An analysis of lesson observations using the formative lesson observation protocol revealed that teachers' practices are lacking in most of the formative assessment aspects. Teachers displayed no attempt to integrate any of the formative assessment aspects into their instructional activities.

Classroom climate

The classroom climate resembled the traditional teacher-centred approach, where the teacher did most of the talking and learners were reduced to passive listeners. Learner autonomy was limited, and learners were not given opportunities to collaboration and support each other. The classroom climate did not support effective teaching and learning as envisaged by the formative assessment approach.

Learning objectives/goals

In all the observed lessons, there was no mention of specific learning objectives at the beginning of the lesson. There was no evidence of the use of learning progression to identify and design incremental learning objectives that, when achieved, would support learners'

understanding of the domain. Learners were only given procedural explanations to complete classroom activity and little effort was made to make learners understand the learning objectives of the activity. The classroom activities given were of low quality and only assessed lower order thinking abilities of learners such as recall of knowledge. The activities were not designed to expose learners' understanding and, as such, teachers made no attempt to address potential misunderstandings and misconceptions.

Monitoring learning

During the lesson, teachers would continuously ask the question "Do we understand each other?" to which the learners would respond collectively with a "Yes". The teachers would then continue teaching without making further attempts to monitor learning. On a few occasions during the lessons, learners were provided with opportunities to respond to questions verbally or in writing. There was a lack of effective questioning strategies (e.g., adequate wait time, open-ended questions) to elicit evidence of learning. Teachers only asked binary questions expecting the "yes/no" or "right/wrong" responses from the learners, and no attempt was made in using learning progression to interpret learner responses.

Giving feedback

As a result of the low-quality classroom activities given and the binary yes/no or right/wrong questions asked by the teachers, teachers were unable to provide learners with meaningful feedback (i.e., information with which a learner can confirm, add to, overwrite, tune, or restructure understanding) that would assist learning. The feedback provided was not in reference to a criterion-based standard and was either limited to evaluation of the learner responses without any explanation or suggestion for alternative strategies to make improvement. The teachers did not provide learners with feedback that described specific areas needing improvement. There was no evidence of teachers using a learning progression to identify the stage where learners are in their learning and where they should be going in their learning.

Self-assessment

In all the observed lessons, learners were not given opportunities to use self-regulatory competencies. Learners were mostly passive listeners or expected to respond to the binary yes/no or right/wrong questions or work on the low-quality classroom activities for which learners were not given opportunities to assess their own knowledge. The teachers made no efforts to develop self-monitoring competencies in learners (i.e., meta-cognitive skills) and learners were not provided with opportunities to make decisions related to their own improvement.

Peer assessment

Learners were not engaged in peer-monitoring. Depriving learners the opportunities to engage with each other meant that teachers were unable to recognise and utilise results of peer activities to strengthen ongoing assessment. Teachers made no effort to utilise peer activities to help learners deepen their understanding of common errors.

Teachers' views and understanding of formative assessment: post-FADC intervention

The same interview schedule that was used pre-intervention was applied for the post-intervention interviews. Teachers' views and understanding of formative assessment showed a positive shift from their views and understandings they possessed prior to the teacher development programme. When the teachers were asked about their knowledge and understanding of formative assessment, they gave responses comprised of at least one element

of formative assessment. This provides some evidence of the impact of the professional teacher development programme. For example, Mr Sithole remarked as follows:

> *Actually, it's more of a discussing-- what needs to be done-- it's more of a matrix of how the teacher and the learner and the information interact. So formative assessment is those assessments which you take from the onset during the learning period all up to the end of the learning period.*

Mr Sithole displayed knowledge which indicates that one of the elements of formative assessment is interaction between the teacher and the learner. In the pre-intervention phase, Mr Sithole defined formative assessment as a step-by-step process, however, he emphasised discussion between teacher and learners after being exposed to the teacher development programme (i.e., post-intervention). Similarly, Mr Luruli showed an improved understanding of formative assessment when he answered:

> *My understanding is that it will help the teacher prepare because there is a goal that you must set that at the end of the lesson, I want to achieve this.*

This is a noticeable shift since Mr Luruli acknowledged no knowledge of formative assessment before engaging in the teacher development programme. In contrast, he was able to point out in his post-intervention response that formative assessment assists teachers to prepare goals to be achieved during the teaching and learning process. Here he was able to proclaim that formative assessment assists when designing learning outcomes. In the post-intervention phase, Ms Mdlalose responded to the question with a noticeable level of confidence and an improved level of understanding as seen in her response below. She was now aware that formative assessment is an ongoing process throughout the lesson and that the aim is to identify gaps in learner learning.

> *I understand a teacher must not just teach but they must assess learners throughout the lesson in trying to check if they are understanding.*

It is evident from the information presented in the preceding paragraphs that the professional teacher development programme had a positive impact on teachers' views and understanding of formative assessment.

Teachers' formative assessment practices: post-intervention

There was a significant improvement in teachers' formative assessment practices post-intervention. Teachers displayed awareness and willingness to integrate aspects of formative assessment in their classroom instructional practices. This is evidenced below.

Classroom climate

In the observed lessons, the teachers made considerable effort to engage learners throughout the lessons. Learners were actively involved by answering questions asked by the teachers. This practise was in sharp contrast to the teacher-centred lessons which were observed during the pre-intervention stage. Teachers were consciously aware of all the learners in their classroom and made efforts to monitor individual learning. This was very evident in Ms Mdlalose's class where she engaged the learners throughout the lesson by prompting them to answer her questions. She also encouraged learners to offer a response to her questions. For example, she engaged one of the learners by urging "Maseko do you want to try, what can you say." This demonstrated a significant shift in classroom from the usual teacher-centred lessons and passive learners' approach that was prevalent during the pre-intervention phase of this research.

Learning objectives/goals

Although the four teachers did not announce the learning objectives at the start of the lesson, they did mentioned the broad topic to be covered. However, within the lesson there was some

attempt to point out to learners the areas they should give special attention to. For example, in one exchange, Ms Lukele told learners "Remember the importance of force on the spacing between particles." Teachers focused on explaining concepts, indicating intentions to address potential conceptual misunderstanding.

Monitoring learning

There was a concerted effort by the teachers to frequently monitor learners' conceptual understanding on an ongoing basis. The teachers used prompting, probing and clarifying questions to keep track of how their learning was unfolding. The use of real-life examples (e.g. the example of the smell of perfume) required learners to apply their knowledge of the particle model of matter to real-life situations and thereby enable the teacher to take stock of their learning. However, there was still no evidence of the use of learning progressions to interpret learners' responses.

Giving feedback

The teachers made efforts to give feedback to the learners, however feedback was still predominantly to correct learners' responses and did not probe learners on reasons for the incorrect responses. The teachers were limited to making correct pronouncements without further amplifications. However, this area showed improvement compared to teachers' practices pre-interventions because they displayed an awareness and appreciation of the value of feedback to learner learning.

Self-assessment

In all four observed lessons, learners were not given opportunities to assess their own knowledge. Not enough time was given to learners to engage on activities individually to assess their knowledge. They were not given the chance to make decisions about their own improvement. There was no shift in teachers' practices on this aspect compared to their practice's pre-intervention.

Peer assessment

Again, learners were not given opportunities to engage in peer-monitoring. Teachers showed no recognition of the results of peer activities to strengthen ongoing assessment and to help learners deepen their understanding of common errors. There was no shift in teachers' practices compared to their practices pre-intervention.

Discussion

The pre-intervention teacher interviews revealed that teachers had either no understanding or a naïve understanding of formative assessment. This is a concern given the importance of formative assessment as a strategy that is used in assessing for learning. The teachers had the sole concept that the purpose of assessment was to make a judgement on the extent to which learning had taken place. In other words ,their understanding was that assessment is purely summative in nature. This is not surprising given that teachers often 'teach to the test' and students often select specific content areas – 'curriculum magnets' (Popham, 2009) – for studying towards their assessments. This aligns with previous research that underscores the persistence of misunderstandings among teachers regarding the nature and purpose of formative assessment (Arrafii & Sumarni, 2018; Schuld, Kanjee & White, 2017). The classroom practices revealed limited evidence of formative assessment with the emphasis being placed on reproduction of scientifically correct information rather than understanding learners' worldviews. Learners' misconceptions were either not revealed or went unnoticed. Little

attempt was made to identify the gaps in learner understanding. There was no evidence of the so-called *on-the-fly assessment* that occurs is associated with formative assessment. The finding on these teachers' understanding of formative assessment align with those of other studies where it was similarly found that teachers have an inadequate understanding (e.g. Arrafii & Sumarni, 2018; Schuld et al., 2017). This is a concern in view of research indicating the benefits of this assessment for learners' academic performance (Black & Wiliam, 1998).

There is research to suggest that it is no easy task to empower teachers with knowledge and skills to enact formative assessment. Although cycles of formative assessment exist to guide formative assessment practices, this assessment is not mechanistic in nature but rather invokes four basic elements of teacher knowledge: 1) domain knowledge, 2) pedagogical content knowledge, knowledge of students' previous learning, and 4) knowledge of assessment (Heritage, 2007). This research adopted the Formative Assessment Development Cycle (FADC) professional teacher development programme. The mixed success of the programme in empowering teachers towards formative assessment reflects on the aforementioned critical elements of teacher knowledge that need to be addressed. With regards to domain knowledge, teachers need to know "the concepts, knowledge, and skills to be taught within a domain, the precursors necessary for students to acquire them, and what a successful performance in each looks like" (Heritage, 2007, p.142). This knowledge is essential for defining a learning progression of subgoals toward the desired learning that will act as the framework to guide assessment and instruction. In this research, in following the FADC cycle, a programme was planned such that teachers were introduced to a learning progression on the particle model of matter. This progression was then used as a scaffold in orientating them towards formative assessment. A lack of the desired impact of the programme in more strongly shifting the practices to integrate formative assessment in their teaching perhaps reflects that these teachers are lacking in the domain knowledge referred to here. While the researchers modelled formative assessment strategies during the teacher development sessions, it is clear this was not adequate for teachers to co-opt such strategies into their teaching. The absence of self- and peer-assessment practices also suggests that teachers may not fully appreciate formative assessment as a participatory, dialogic process. For formative assessment to foster metacognitive growth and student agency, learners must be empowered to regulate their own learning through self-assessment and peer dialogue (Goradia, Blackley, Southam & Lareu, 2023). In order for teachers to conscientiously and sustainably adopt formative assessment practices, they will need to be given further opportunities to reflect upon their classroom actions. Embedding learning progressions into curriculum and textbook design may bridge this gap and promote coherence across policy, pedagogy, and assessment.

Limitations

While this study offers insights into how a learning progression can scaffold teachers' formative assessment practices, limitations must be acknowledged. First, the study was conducted with a small sample of four teachers from three rural, under-resourced schools in a single district, which limits the generalizability of the findings. Second, the duration of the professional development programme and the time allocated for classroom implementation may not have been sufficient to observe sustained or deeper pedagogical shifts. Formative assessment practices require iterative engagement and longer-term support to be meaningfully embedded in teaching practice.

Conclusion

The findings of this study suggest that formative assessment and the associated four basic elements of teacher knowledge needs to be addressed in pre-service teacher education and also in continuous teacher development. Furthermore, formative assessment should be linked to a learning progression that can provide a map of what is to be learned and a continuum of how learners are expected to progress. The research clearly showed that the participant teachers did not even have the term learning progression in their vocabulary. It is likely that it had not been addressed in their teacher education. Furthermore, curricula documents that specify content to be taught do not make any reference to a hypothetical framework of core ideas in a domain, and how these ideas are built upon over a span of time. Curriculum planners and textbooks writers should give more explicit attention to how they present content in a manner that is informed by learning progressions.

References

Arrafi, M. A., & Sumarni, B. (2018). Teachers' understanding of formative assessment. *Lingua Cultura, 12*(1), 45-52.

Ahmed, A., & Winberg, C. (2024). Inclusive formative assessment in work-integrated learning from the perspectives of students with disabilities. *International Journal of Work-Integrated Learning, 25*(1), 141–154.

Bennett, R. E. (2011). Formative assessment: a critical review. *Assessment in Education: Principle, Policy & Practice, 18*(1), 5-25.

Black, P., & William, D. (2009). Developing the Theory of Formative Assessment. *Educational Assessment, Evaluation and Accountability, 21*, 5-31.

Duschl, R. (2019). Learning progressions: framing and designing coherent sequences for STEM education. *Disciplinary and Interdisciplinary Science Education Research, 1(*4), 1-10.

Furtak, E. M., Kiemer, K., Swanson, R., & Circi, R. (2015). Learning Progressions, Formative Assessment, and Professional Development: Results of a Longitudinal Study. Paper Presented at the National Association of Research in Science Teaching Annual Meeting, Chicago, IL.

Furtak, E. M., Roberts, S., Morrison, D., Henson, K., & Malone, S. (2010). Linking an educative learning progression for natural selection to teacher practice: Results of an exploratory study. Paper presented at 2010 Annual Conference of the American educational Research Association, Denver, CO.

Furtak, E. M., & Ruiz-Primo, M. A. (2008). Making Students' Thinking Explicit in Writing and Discussion: An Analysis of Formative Assessment Prompts. Science Education, 92, 799– 824.

Gengle, H. I., Abel, M. A., & Mohammed, B. K. (2017). Effective Teaching and Learning Strategies in Science and Mathematics to Improve Students' Academic Performance in Nigeria. *British Journal of Education, Society & Behavioural Science, 19*(1), 1-7.

Goradia, T., Blackley, S., Southam, D. C., & Lareu, R. R. (2023). The effectiveness of evidence-based teaching practices in biomedical sciences on students' learning experience: A systematic literature review. *International Journal of Innovation in Science and Mathematics Education, 31(*1), 55–66.

Heritage, M. (2007). Formative Assessment: What Do Teachers Need to Know and Do? *Phi Delta Kappa, 89*(2), 140-145.

Lim, N.T-L, Lee, Y-J, & P.P.F., Lee (2023). What types of feedback do undergraduate chemistry students give each other? A case study from Singapore. *International Journal of Innovation in Science and Mathematics Education, 31*(2), 34-46.

Mabena, N., Mokgosi, P., & Mamapela, S. S. (2021). Factors contributing to poor learner performance in mathematics: A case of selected schools in Mpumalanga province, South Africa. *Problems of Education in the 21st Century, 79*(3), 451-466.

Miles, M. B., & Huberman, A. M. (1994). Qualitative Data Analysis: An Expanded Sourcebook. Thousand Oaks, CA: Sage Publications.

Mohan, L., Chen, J., & Anderson C. W. (2009). Developing a Multi-Year Learning Progression for Carbon Cycling in Socio-Ecological systems. *Journal of Research in Science Teaching, 46*(6), 675-698.

O'Neill, S. (2013). Effective teaching. Australia: The Government of Western Australia.

Oswalt, S. G. (2013). Identifying Formative Assessment in Classroom Instruction: Creating an instrument to observe use of formative assessment in practice (Doctoral Thesis). Boise State University.

Popham, W.J. (2009) Assessment Literacy for Teachers: Faddish or Fundamental? *Theory Into Practice, 48*(1), 4-11.

Reddy, V., Visser, M., Winnaar, L., Arends, F., Juan, A., Prinsloo, C., & Isdale, K. (2020). *TIMSS 2019: Highlights of South African Grade 9 Results in Mathematics and Science*. Human Sciences Research Council.

Rosenberg, E, Nsubuga, Y and Burt, J (2009). Quality and Relevance in South African Schooling: Implications for human capital development in the environmental sector. Rhodes University Environmental Education and Sustainability Unit, Grahamstown.

Saldana, J. (2013). The Coding Manual for Qualitative Researchers, 2nd ed. LA: Sage Publications.

Schuld, N., Kanjee, A., & White, T. (2017). Tinder or flint: Igniting Grade 2 teachers' understanding of learning, teaching and assessment. *Journal of Education, 70*, 109-132.

Sevian, H., & Talanquer, V. (2014). Rethinking chemistry: a learning progression on chemical thinking. *Chemistry Education Research and Practice, 15*, 10-23.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.