

CHAPTER 5

ASSESSMENT PRACTICES OF MOZAMBICAN PHYSICS TEACHERS

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This chapter reports on the findings of the Baseline Survey aimed at investigating assessment practices used by Grade 12 Physics teachers in the classroom and designed to inform the Intervention Study. Section 5.1 presents the introduction to the chapter where the aim of the Baseline Survey is formulated and discusses the preliminary literature findings about what is already known on teacher assessment practices. Section 5.2 presents and discusses the main findings of the Baseline Survey with emphasis on the assessment practices used by teachers, their frequencies, their quality, and their relevance for student learning. The section also reveals the reflections drawn from interviews with school directors, pedagogical officers and assessments experts. Finally, the conclusions and recommendations as to what aspects can be taken into account when preparing the intervention phase in order to produce improvements in the teachers' practices are presented in Section 5.3.

5.1 Introduction

The aim of this study is to investigate and improve the assessment practices used by secondary school Physics teachers in Mozambique. As was discussed in earlier chapters (refer to Chapter 1, Section 1.2 and Chapter 4, Section 4.3) in order to address this aim, it was necessary to start by undertaking a preliminary survey aimed at identifying assessment practices currently used by Grade 12 Physics teachers in Mozambican schools. Specifically, a Baseline Survey was carried out to investigate what assessment practices Grade 12 teachers currently apply in Physics at classroom level.

Some studies have investigated the assessment strategies used by Mozambican teachers (INDE, 2005; Lauchande, 2001) and by other teachers elsewhere (Race et al., 2005; Popham, 2002) when assessing science subjects. According to these studies, and as has been referred to in Chapter 1 (Section 1.2), generally the present assessment practice in Mozambican education is fundamentally based on expecting from students the memorisation of concepts, formulas and mechanisation of procedures due to the teachers' weak scientific and pedagogic competence, and to the lack of skills in developing appropriate assessment instruments. This situation is more accentuated in experimental subjects, such as Physics, where teachers do not teach, and hence assess, the student abilities to manipulate, to observe, to generalise, and to establish relationships. According to these studies, this is due, on the one hand, to the teachers' weak preparation for teaching and assessing these abilities, and on the other hand, to the lack of teaching material and equipment such as microscopes and some other electric appliances. Apart from these teachers' difficulties, the studies have also recorded some student weaknesses. Students are seen to have difficulties in answering essay-type questions as their writing skills are inadequately developed. As is the case with other subjects, in the assessment of Physics greater attention is given to marking and grading, instead of providing formative feedback, much of which tends to lower self-esteem of both students and teachers. Not enough advice is provided for the improvement of both learning and teaching. This is the baseline information available from the very few studies conducted in Mozambique in this regard.

Internationally, Race et al., (2005) for instance, report that there is an overemphasis on norm-referenced type of assessment, where students are compared with each other and this leads to demoralisation among the less successful students. Peer-assessment amongst students, i.e., the way teachers are supposed to allow students to assess the work of their colleagues, is also another weak point in Physics classroom assessment. In this regard, Race et al., (2005) point out a number of assessment strategies that can be used by teachers to involve students in peer-assessment. These strategies include (i) student presentations, (ii) reports, (iii) essay plans, (iv) calculations, (v) interviews, (vi) annotated bibliographies, (vii) practical work, (viii) poster displays, (ix) portfolios, (x) performances, and (xi) exhibitions and artefacts. Only a very few of these strategies are

used in schools as a means of allowing students to assess their own work and that of the others. Still according to these authors, teachers' feedback to students often serves managerial and social purposes rather than helping them learn more effectively. For instance, during Physics lessons, teachers tend to give feedback to students individually and not to groups, and this situation does not allow students to learn from the successes and failures of others. This situation is also seen to prevent them from questioning the teacher and challenging his/her comments.

Within this framework, the present Baseline Survey was aimed not only at finding out what assessment strategies are used by teachers in schools but also at reporting on their quality and relevance for assessing Physics. This information served as a platform to start an Intervention Study aimed at realising improvements of the teacher assessment practices. This chapter presents and discusses the fieldwork findings of the following operational research question: *What assessment practices do Grade 12 teachers in Physics in Mozambique apply and what is their quality?*

During the Baseline Survey, both qualitative and quantitative methods were applied to collect and analyse data with the main aim of understanding the characteristics of the current teacher assessment practices, and to produce valuable information needed for designing the Intervention Study. In fact, the above-mentioned operational research question is the starting point for designing and developing an appropriate intervention. This reasoning is in line with Creswell's (2003) research paradigm used to guide the present study and referred to in Chapter 1 (Section 1.3).

5.2 Findings of the Baseline Survey

As has been mentioned in the Survey research design (Chapter 4, Section 4.3) three elements were used as perspectives against which the characteristics of assessment practices used by teachers in schools are described, namely the *types* of assessment practices applied (defined by their frequency), their *quality*, and their *relevance* for learning. These elements were used to guide the formulation of the operational research

questions of the Baseline Survey. This subsection presents and discusses the findings of the Baseline Survey according to these elements and follows the sequence in which the findings answered the corresponding operational research questions.

5.2.1 Assessment practices applied and their frequencies

According to the literature review (Chapter 3), several authors have indicated a number of assessment strategies that teachers normally use in schools. The aim of the Baseline Study was to identify which assessment strategies Mozambican Grade 12 teachers use when assessing their students and what can be said about the quality of these. Findings were derived mainly from the questionnaire administered to twelve teachers including four school directors. The main question addressed to teachers in order to identify the *types* of assessment practices and viewed from the perspective of their frequency was: *How often do you use each of the following assessment practices: portfolios, peer-assessment, verbal tests, homework, paper-and-pencil, projects?* Answers were elicited and the findings were supported by interviews with all twelve teachers, with two pedagogical officers and by eight classroom observations by the researcher. The main findings summarised in Figure 5.1, related to the assessment practices commonly used by teachers in schools and their frequencies indicate that paper-and-pencil tests, verbal tests and homework are the most frequently used assessment practices in schools.

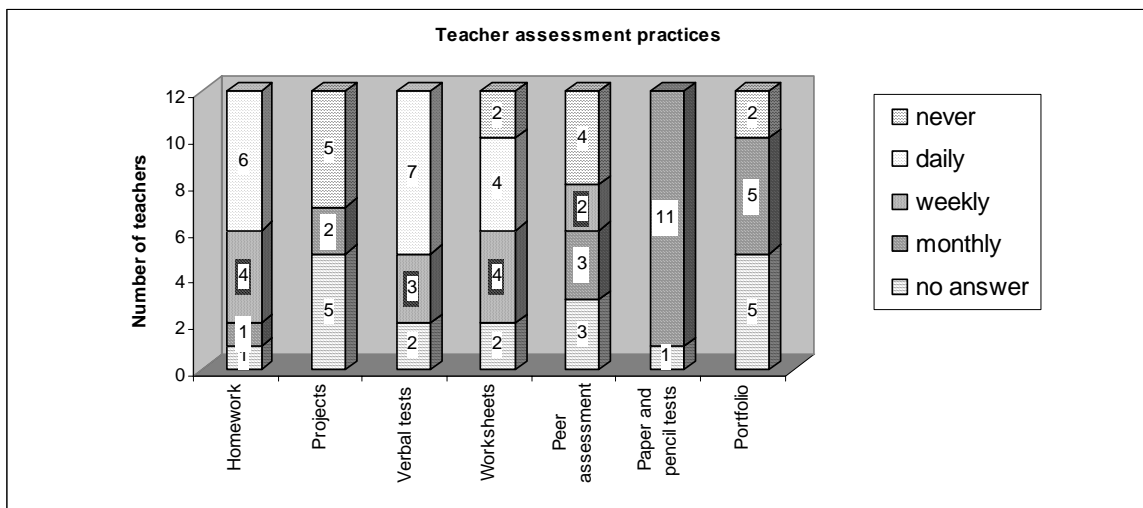


Figure 5.1: Teachers’ responses by type of assessment practice (n=12)

Eleven (n=12) teachers said they were using paper-and-pencil tests (one did not respond), and grading homework (six daily, four weekly, and one monthly). Verbal tests were used by ten (n=12) teachers (seven daily and three weekly). Verbal tests are oral questions that teachers ask during the course of the lesson to students and which require immediate answers. The less frequently used assessment practices were projects and peer-assessment. Five teachers said that they never assessed by means of projects and the same number of teachers did not respond to the question. Only the remaining teachers (two) said that they assess through projects monthly. Four teachers never used peer-assessment.

A first analysis of these results raised a concern about the number of missing data in the questionnaire. A large number of teachers did not provide answers to some of the assessment practices: five teachers (n=12) for projects, the same number for portfolios assessment, and three teachers for peer-assessment. This was most likely due to the teachers' poor understanding, sometimes lack of it, of the different assessment practices. Therefore, there was a need to verify what could have been the cause. The findings were triangulated by the interviews with the aim of clarifying the unanswered questions and also eliciting the answers provided by the teachers. During the interviews, teachers were asked to explain their understanding of some of the assessment practices and to say whether they used that type of assessment in their classrooms.

The answers showed that some of the teachers did not use some assessment practices because they were not familiar with that particular practice. In addition, they showed a lack of clarity between what they do in the classroom and what they were actually being asked by the researcher. For example, the following quotation from an interview with a teacher is evidence of the level of teachers' understanding (or lack of it) about portfolios assessment:

[Male, 41 years old, Pemba Secondary School, Cabo Delgado Province]

Interviewer (Ivr): what do you understand by portfolio assessment?

Teacher (Tch): (...) silence...sorry I did not understand the question.

Ivr: what is your understanding of portfolio assessment?

Tch: Huumm,...I do not know about this.

Ivr: Ok. Have you ever determined a student's progress through his/her particular work?

Tch: Ah... yes. We always do this at the end of each semester when we meet as the Physics group of teachers to evaluate the performance of individual students' work and discuss their final scores. We do this twice a year.

Other evidence of teachers' lack of understanding of some of the assessment practices was found in relation to peer-assessment. Some of the teachers expressed the idea that they feel uneasy using peer-assessment because they feel students are not supposed to assess their own work or that of their peers because they think they are all students and that is why they are in school – just to learn. In an interview about the use of peer-assessment one teacher said:

[Male, 28 years old, Chókwè Secondary School, Gaza Province]

I do not think it's a good idea at all (doing peer-assessment in the class). How can you expect somebody to assess other somebody's work without knowing him or herself about it? ...furthermore, I think students... will never feel easy doing this job! You know... they're friends and would not like to give each other's low marks ... just in case if the work was wrongly done. Better I do it myself; I am the teacher, after all.

These answers show that teachers (at least some) were not quite familiar with certain of the assessment practices such as portfolios and peer-assessment, and they lacked insight into the value of using these when designing assessments and administering them in the classroom. Judging from the evidence produced by the interviews, it seemed that this lack of understanding could be the reason for high number of teachers not assessing students using projects or portfolios.

It is worthy mentioning that in Chapter 4, it was referred that a piloting of the all instruments was undertaken (subsection 4.3.3), and that the internal reliability was carefully established in order to ensure that the respondents answered related items in a similar way (refer to Section 4.5). However, this seemingly unfamiliarity of the teachers with some assessment practices was probably not detected during the pilot process because the level of exposure to educational resources (e.g., libraries and bookshops) and

events (seminars, workshops, in-service courses, etc.) decreases as one moves from Maputo to the North. In fact, the first excerpt quoted above is from a teacher from Pemba Secondary School, which is located in the northern region of the country about 2,500 km away from Maputo. However, in order to limit the costs, the pilot phase was undertaken in Maputo schools only, while the Baseline Survey took place in schools countrywide, excluding Maputo. This was a deliberate choice, as one of the aims of the study is to help the most disadvantaged teachers from the provinces. It might, however, be possible that some of the Maputo teachers had also some difficulties in understanding some of the assessment practices but, for some reason or another (not explained by the study findings), the pilot process did not uncover this. In the end, however, it is fair to acknowledge that the decision may have influenced the validity of the instruments at some extent.

Another concern resulting from the analysis of the data is the lack of consistency in teachers' responses from the questionnaire to the interview. For instance, during the questionnaire two teachers said that they were using projects, five of them used the portfolios, and the same number used peer-assessment. However, during the interviews, ten teachers said they had never assessed using projects, eleven said that they had no idea of what a portfolio was, and nine said that they had never used peer-assessment. Table 5.1 shows the difference between teachers' responses to the questionnaire and what emerged from the interviews.

Table 5.1: Consistency level of teachers' responses between questionnaire and interview (n=12)

	Portfolios		Projects		Peer-assessment	
	Questionnaire	Interview	Questionnaire	Interview	Questionnaire	Interview
Yes	5	1	2	2	5	3
No	2	11	5	10	4	9
No answer	5	-	5	-	3	-
Level of consistency	Among the eleven teachers who said NO in the interview, five were those who did not respond in the questionnaire, two are the same who said NO in the questionnaire and four changed their minds from the questionnaire to the interview.		Among the ten teachers who said NO in the interview, five were the same who also said NO in the questionnaire and the other five were those who did not respond in the questionnaire. The two who said YES, stuck to their answers.		The number of teachers who said NO in the interview (nine) is made up of the same four who have also said NO in the questionnaire, plus three of those who did not respond. Two of them changed their minds from the questionnaire to the interview.	

The first impression arising from these data reinforces the idea that, most probably, the amount of missing data in the questionnaire reflects the teachers' poor understanding of the different assessment practices. For instance, as far as the portfolios is concerned, all of the five teachers, who did not respond in the questionnaire to the question about using portfolios, quite openly said they never used portfolios, and still four out of the five who said they used portfolios during the questionnaire appeared to change their minds in the interview when they had a better understanding of the concept. Teachers changed their minds after having been informed during the interview what a portfolio was. The same applies to projects and peer-assessment where all the missing data from the questionnaire turned into NO answers.

Although one can conclude, after the interviews, that the majority of teachers seem not to use these assessment practices, the consistency of responses that were given after an explanation from the interviewer still remains questionable. It is not clear whether the

teachers' responses were honest or whether they wanted to please the interviewer. Furthermore, the teachers' unfamiliarity with these assessment practices, which was apparent during the interviews, reinforces the lack of consistency in their responses.

As for the most frequently used assessment practices (paper-and-pencil tests, verbal tests and homework), there were no substantial differences between teachers' responses from the questionnaire to the interview. All of the missing data turned into YES responses, most probably because these are seemingly more popular assessment practices amongst teachers.

So, it would seem that the teachers' most consistent results, in terms of the types of assessment practices, are paper-and-pencil tests, verbal tests, and grading homework where the majority of teachers (more than ten teachers out of twelve) said that they use these assessment practices daily, weekly or monthly.

5.2.2 Quality of assessment practices

One of the ways used to investigate the quality of assessment practices used by teachers in schools was to ask teachers the following question: *How often do you assess the following students' activities: oral communication during lessons, written work, presentations, notebooks, laboratory work, solving problems?* In fact, a frequency in itself is not a good indicator for quality because a teacher can frequently use certain assessment practice of poor quality. However, available literature indicates that classroom assessment in the Mozambican context is exam-driven and constantly using a certain assessment practice can reveal the teacher's interpretation of the quality of that practice as seen by the MEC (Lauchande, 2001; Palme, 1992; Popov, 1994). This information helps to understand how the quality of classroom assessment can be influenced by external examinations as it was later confirmed by the pedagogical officers during interviews. Furthermore, it was also expected that by asking teachers to reflect on these different student activities it would be possible to understand the validity (in terms of content) of the assessments being undertaken by and with students (Chapter 4, Section 4.3).

This is an important starting point for understanding and interpreting the study findings. A 5-point scale was used to characterise the frequency of the use by teachers of the activities: no answer, always (1-2 times per week), frequently (1-2 times per month), sometimes (1-2 times per semester), never. It is relevant to note that, according to the syllabus, Physics lessons for Grade 12 are delivered two days per week with a 90-minute class session on one day, and a 45 minutes session on the other day. For this particular question, it is important to note that, when it comes to establishing comparisons between the findings, one should bear in mind that the frequency level varies from one activity to another. For example, while in a real classroom situation the assessment by means of oral communication is one of the most frequently used activities, the assessment of students' notebooks cannot be done on, for instance, a daily basis. This means that the 5-point scale cannot be literally applied without taking this reality into consideration. Findings from this question, which were also collected through the questionnaire, are summarised by the Figure 5.2 presented below (n=12).

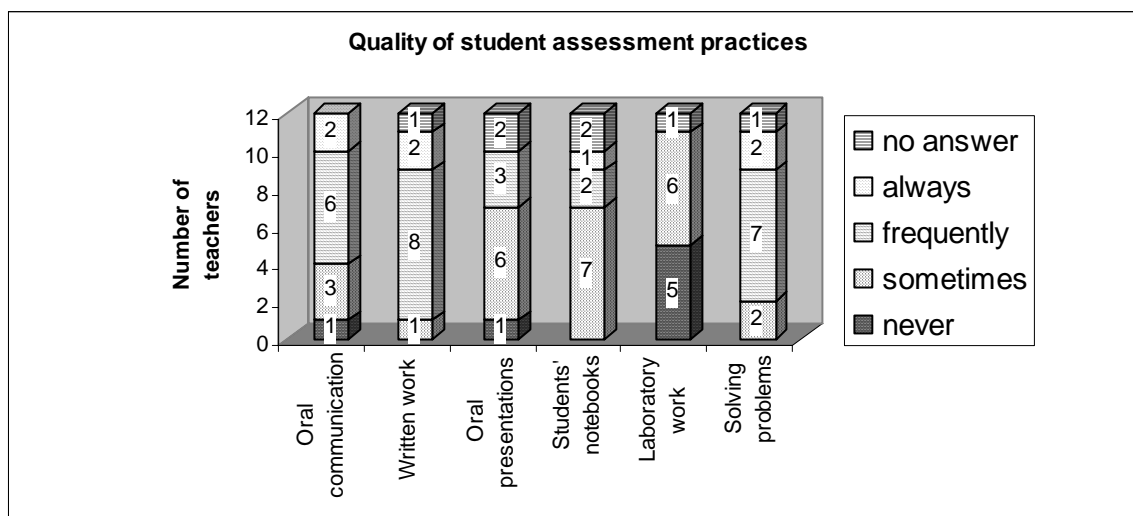


Figure 5.2: Teachers' responses on the assessment of students' activities (n=12)

The most assessed student activities are written work and providing feedback on student ability to solve problems (both used by eleven out of twelve teachers), where only one teacher gave no answer to each of them. Laboratory work is the activity that is never assessed by many of the teachers (five) or is assessed sometimes (six teachers). These findings were also triangulated using interviews. During the interviews, it became apparent that the teachers did not have the same understanding of the meaning of solving

problems. For some of them, solving problems only meant doing exercises in the classroom or at home using calculations. Perhaps a good understanding of the meaning of ‘solving problems’ could lead to different teachers’ responses to this particular activity. In the context of the question asked by the study, ‘solving problems’ meant not only the student ability to devise solutions based on mathematical calculations, but, more importantly, referred to generating solutions of given real-world problems, for instance, by correctly setting up an electrical appliance.

Bearing in mind that the frequency alone is not enough to verify the quality of assessment practice there was a need to consider another way of investigating quality. Another way of investigating this was the analysis of some paper-and-pencil tests - one of the most frequently used assessment practices - given by teachers to students. A sample of 43 student tests, which had already been corrected by the teachers and handed out to students, was collected and analysed. The tests were randomly collected from six out of the twelve participating teachers – one teacher in each school. Five teachers brought seven tests each and the sixth teacher handed in eight tests. The reason for considering only one teacher in each school is that the tests collected were ACP (Activities of Partial Control given three times per semester) that are prepared by subject groups in schools. It was assumed that the characteristics of the other teachers and of the other teachers’ tests would be the same or quite similar. The purpose of this analysis was not only to cross check the information given by the teachers during the questionnaire, but also to investigate the quality of feedback given to students by teachers when they assess the students’ written work. Since the written work was identified as the most assessed type, an aspect of interest for the analysis was to verify how the teachers knew their students were making progress on this particular type of assessment practice. Specifically the analysis concentrated on the formative function of assessment through verifying how teachers were monitoring student learning and providing feedback.

Therefore, three aspects of formative assessment guided this analysis, namely the distinction between good and poor feedback (articulation), the time spent by teachers for

providing feedback (time), and the way the feedback was given (personality) (Race et al., 2005).

The following positive aspects of formative feedback were revealed during the analysis of the tests.

- *Articulation* - the feedback of the teachers include clear indication of the quality of work done by students, whether it was good (favourable mention) or poor (critical mention).
- *Timeliness* - most of the teachers gave their feedback timely while moving from one desk to another.
- *Personalisation* - the feedback was mostly given to students in an individualised form, which means that teachers made an effort to give feedback on each student's personal achievement.

One negative aspect in teachers' feedback to students that emerged from the analysis was related to the lack of input given to students in order to empower their learning. Although the teacher feedback was well articulated in terms of favourable or critical comment to the students' work, most times teachers did not provide directions needed to enhance the students' strong aspects (favourable) of learning or to improve their areas of weaknesses (critical). To worsen the situation, the language used by teachers included very strong words particularly for poor works (e.g., 'bad', 'very poor'). This type of feedback can dampen any enthusiasm for learning for most of the students (Race et al., 2005).

Given this situation, it can then be concluded that the assessment practices used by teachers in schools are still not of a good quality. This emerges, firstly, that even though several activities may be used to assess student learning of Physics, written work appears to be the one most used by teachers. Laboratory work, solving problems and oral presentations, deemed relevant for assessing student learning of Physics, are not included in assessment practices. Secondly, the way teachers monitor student learning and provide feedback is poor and consequently, requires substantial improvements.

5.2.3 Relevance of assessment practices

Two specific research questions were asked related to the relevance of assessment practices namely (i) *How do you engage students in the evaluation of their performance?* and (ii) *How often do you use the assessment results in class teaching and assessment?*

In relation to the first question, six alternative options were given to teachers (to select ‘all that applied’) and they are listed below.

- *I do not involve them at all* – students are not involved in the evaluation of their performance in any way.
- *By handing out the results* – students are given the results of their assignments without any relevant feedback.
- *By involving them in self-assessment* – students are given back their assignments and they are allowed to discuss amongst themselves about their own strong and weak points in the assignment.
- *By sharing with them the goals to be achieved* – students discuss and share with the teacher the assessment objectives to be achieved before they engage in the assessment task.
- *By explaining the implications to them* – students are given the opportunity to reflect on the consequences of achieving or not the expected learning outcomes, particularly for graduation purposes (classification of students and setting of standards).
- *By reflecting with them on the assessment data* – students reflect with the teacher about the assessment results (e.g., excellent and poor results) in order to learn from each other’s successes and failures.

The level of student involvement in the evaluation of their own work is seen to be an indicator of how well, or not, the students become aware of the importance of their performance, particularly when they peer assess (Race et al., 2005). Furthermore, Popham (2002) points out that by sharing with students the goals to be achieved and letting them

know what is expected of them helps, for instance, to achieve that goal. Below are the findings of this question (i), which were also mainly collected through the questionnaire.

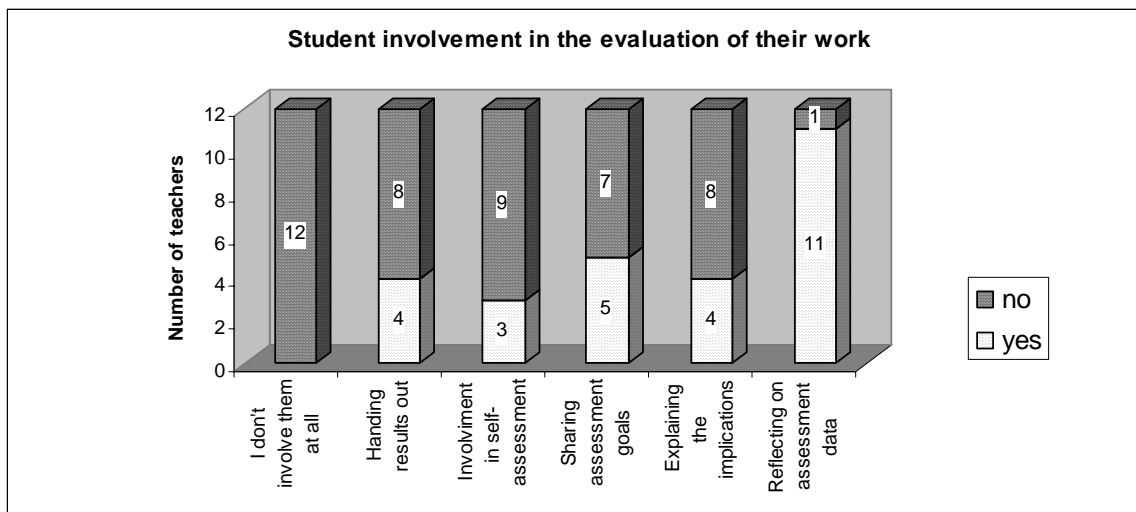


Figure 5.3: Teachers’ responses on students’ evaluation of their work (n=12)

The most common way used by teachers to get the students involved in the evaluation of their performance is reflections with them about their assessment results in order to motivate them to learn from their successes and failures. This is shown by ‘reflecting on assessment data’ type of teachers’ responses given by eleven teachers (n=12). Self-assessment was less used by teachers to evaluate the student work (three out of twelve teachers).

During the interviews, however, it appeared that some of the teachers’ responses to this question were contradictory. For instance, all twelve interviewed teachers referred to the fact that they never allowed students to assess their own work and only rarely allowed them to assess that of their fellow students. By “reflecting on assessment data” they meant summing up how many students got negative marks (0 to 9) and how many got positive marks (10 to 20). The formative element of assessment is not addressed. Interestingly, all teachers (n=12) said that they do not involve students in the evaluation of their work at all. This answer did not come as a surprise because, although the Mozambican curriculum for secondary education to be introduced soon advocates the constructivist approach of teaching and learning, teachers in schools are still employing the traditional teaching style characterised by a strong teacher-centred pedagogical approach. The analysis of the

findings also shows that some teachers’ responses were not consistent. This is shown by the number of teachers who engage students by handing out the results and by reflecting with them on the assessment data. In fact, what was seen during classroom observations and also supported by some interviews (eight teachers), these two activities more often occurred simultaneously, i.e., the handing out of the results is always accompanied by the reflection with the students on the assessment data.

Finally, the question on relevance of assessment practices was investigated by asking teachers the question (ii) *How often you use the assessment results in class teaching and assessment?*

Four categories were identified to serve as objectives that the assessment results can be used for namely: (i) to assign grades; (ii) to identify students’ strengths and weaknesses; (iii) to help students know and recognise the standards they are aiming for; and (iv) to encourage active involvement of students in their own learning. A 4-point scale was used to show the frequency of the use by teachers of each of these categories: no answer, sometimes (once per semester), frequently (2-3 times per semester), and always (more than 3 times per semester). Figure 5.4 shows the findings.

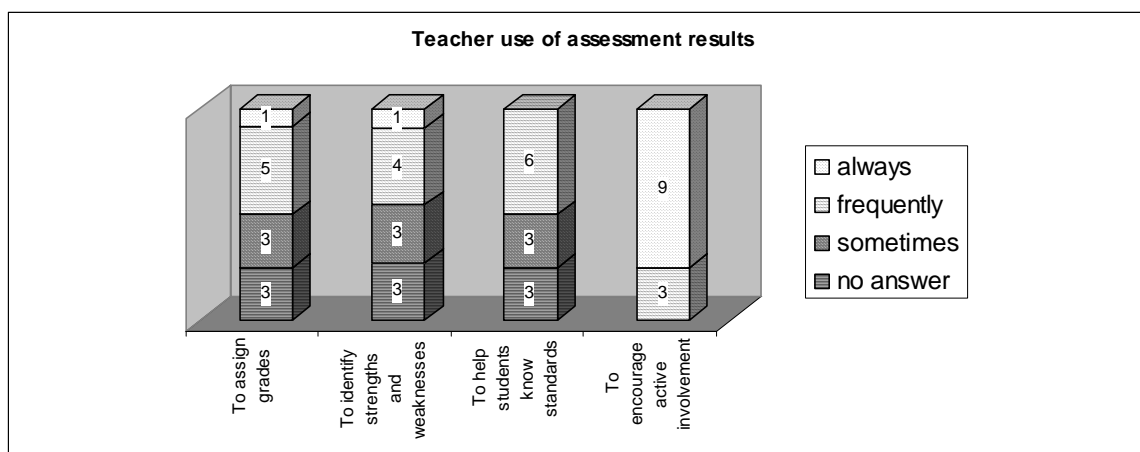


Figure 5.4: Teachers’ responses on the use of assessment results (n=12)

Encouraging students to engage in active involvement in their learning is the assessment objective referred to most by the majority of teachers (nine out of twelve). However, an analysis of these findings shows that about one quarter of the teachers did not provide answers to each of the first three categories of assessment objectives and the same number

used the assessment results for these purposes only once per semester (sometimes). This means that very crucial aspects of classroom assessment like diagnosing student strengths and weaknesses, as well as sharing goals with the students have not been taken into consideration by a large proportion of the teachers. Alternatively, the number of teachers who said they *always* used the assessment results, for whatever category, is low: one for assigning grades, another one for identifying strengths and weaknesses, and none for helping students to know the standards. One relevant aspect to consider when analysing these findings is the relatively high number of teachers who said they used the assessment results *sometimes* and *frequently*. As seven teachers referred to it during interviews, these answers refer to the activities in which teachers of the same subject meet to analyse the student performance after an ACP (Activity of Partial Control) – given three times per semester – or when teachers of different subjects analyse the overall performance of the students at the end of the semester. According to the teachers, this analysis is merely statistical and it is aimed to get indications on how students are progressing towards the transition to the following grade level. Activities like item analysis or some other reflections with diagnostic or remedial purposes are rarely taken into consideration during these meetings.

So, in conclusion, if the level of student involvement in the evaluation of their performance is restricted to a mere *reflection on the assessment data* (mainly aimed at inferring pass and fail marks) without using the data for feeding the teaching and learning process, and if the number of teachers who *always* use the assessment results is very low, then it is fair to question the relevance of the teacher assessment practices for student learning of Physics. To worsen the situation, even those teachers who always use the assessment results, this usage is not directed toward the improvement of the teaching and learning of Physics in general. This suggests that, although in the early versions of the prototypes a priority should be given on helping teachers to design good learning materials – as referred to in Chapter 4, subsection 4.3.2.3 – it reinforces the idea that an added attention should be placed at the later versions on quality basic assessment practices and feedback.

5.2.4 Reflections from school directors, pedagogical officers and assessment specialists

The purpose of interviewing school directors and pedagogical officers and of consulting assessment specialists in the MEC was twofold. Firstly, there was a need to cross check the information provided by teachers in the questionnaires and interviews, and the one derived from researcher's classroom observations. Secondly, it was important to know to what extent the objectives of final assessments (examinations) carried out by the Ministry of Education and Culture to Grade 12 students are met as compared to the objectives of classroom assessment carried out by teachers in schools. Specifically, this second purpose is addressed in questions about the *level of teachers' preparedness to conduct formative assessments in schools, the relationship between the information provided by the teacher assessments in schools and that collected by the Ministry's final exam, and the evaluation of the student performance* at the end of the year.

Data from interviews with pedagogical officers indicate that the types of assessment practices carried out by teachers in schools address questions that basically ask students to mention or describe facts or phenomena, but they do not promote the establishment of relationships between these facts, or any comparison and explanations of causes and consequences of such phenomena. Still according to the referred sources, these characteristics of teacher assessments are determined by the teaching strategy, which focuses more on the memorisation of facts. Notes from assessment specialists reinforced this perception. They indicated that, as a result of this situation, the final exam from the Ministry of Education and Culture has also been negatively influenced, firstly, because it is prepared in consultation with teachers and secondly, because it would not be pedagogically desirable to introduce, via national exams, radical changes into the assessment system, which were not dealt with during the teaching and learning process. Both sources are of the opinion that, in comparing the results of the teacher assessments and of the examinations, those from the exams have been relatively low. The sources argue that this situation, however, should not be interpreted as resulting from low levels of achievement demanded by the teacher assessment as compared to the examinations.

Seemingly, the fact that, during examinations, students from different social and regional backgrounds, taught by different teachers, and studying in different learning environments and conditions write the same exam papers and are assessed at the same time, is leading to a counter-productive effect on the student performance. Without any supported evidence, however, one can only argue that there is a need for an in-depth reflection about the quality of both teacher assessments and examinations from the Ministry because several studies have reported teachers' poor skills in preparing acceptable test items, as well as the substandard quality of the exam papers. The Ministry of Education and Culture is conscious of this fact, which it addresses in the revised curriculum of secondary education, by putting more emphasis on supporting teachers in preparing and administering acceptable tests. In light of this complex situation, the interviewees, particularly the pedagogical officers, are of the opinion that one of the solutions to address the problem of quality formative assessment and of the comparability of the information of the two assessments, is to introduce what they call an 'exercise book' containing different types of test items addressing various student skills and competencies to help teachers prepare appropriate classroom assessments. These exercise books should be introduced in teacher training institutions to help the preparation of teachers for classroom assessment because according to the interviewees, the teacher trainers themselves appear to have difficulties in developing appropriate assessment tools.

On the question of the teacher preparedness to conduct formative assessment, both school directors and pedagogical officers pointed out the fact that, more often than not, teachers complain about the large class sizes. Teachers argue that there is no favourable environment to conduct formative assessment in such overcrowded classrooms. This is the reason why, according to the interviewees, the assessment has turned into a mere administrative process by which teachers provide mainly statistics about pass and fail marks and it does not reflect the real situation in terms of the extent to which the teaching and learning objectives have been met.

In relation to the evaluation of the student performance, the pedagogical officers refer that the Ministry's policy is that, when teachers submit the results of the final examinations,

they should include a report in which they indicate the main areas of students' difficulties, the most common errors the students have committed, some identified misconceptions or other alternative conceptions about facts and phenomena. They argue that the reality, however, is that these reports, if submitted, are of very low quality in terms of problem diagnosis. Teachers also complain again about the high number of students per class, which does not allow any in-depth analysis or diagnosis of the most problematic areas.

In summarising the information provided by these sources, it can be concluded that teachers are poorly prepared for conducting effective formative assessment of their students and they seem to face difficulties in preparing appropriate assessment tools. The high number of students per class worsens the situation. Interestingly, the national examinations undertaken by the Ministry are levelled from bottom, i.e., they depend on the quality of the classroom assessments that is reportedly low. The fact is not that the Ministry is in compliance with low levels of performance but, in practice, exam designers seem to be uncomfortable in instilling quality changes into the exams fearing that the standard levels will drop even more. As a result, the assessment process does not feed the teaching and learning process. Teachers are not providing valid reports about important areas of students' strengths and weaknesses. Given the fact that findings indicate that the results of the exams are lower than those of the teachers' assessments and that student difficulties are not diagnosed and monitored, it is fair to question the overall quality of the assessment system in general. The quality of feedback provided by teachers to students is fundamental in any procedure of classroom assessment and be central to the teaching and learning process as a whole. This feedback is effective only if it addresses the identified heterogeneous student needs (Black & William, 1998). But in the context of large classes, this is a challenge that should not be the responsibility of teachers alone but should be addressed in teacher training institutions in terms of how to adopt effective teaching and assessment strategies. The aspect of classroom management, which is a crucial issue in the context of large classes, is another challenge that needs particular attention from all decision makers and educational stakeholders. While effective classroom management and implementation of formative assessment is likely to be successful when the teacher has more teaching experience, resulting in solid pedagogical content knowledge, the most

experienced teachers are the ones who most frequently resist changes. There are many variables involved in collecting and analysing data to provide effective feedback to teaching and learning, which demands both technical and professional knowledge not always present in teachers with so many years of teaching experience. These teachers normally follow their teaching routines, which do not always accommodate suggested innovations. The suggested idea of introducing ‘exercise books’ seems to be one of the crucial measures for supporting teachers in conducting effective formative evaluation, particularly in the context of the current curriculum review.

5.3 Conclusions

At the outset of this chapter, it was stated that the objective of the Baseline Survey was to identify assessment practices used by Grade 12 teachers in schools as a way to inform the Intervention Study aimed at producing improvements on the teachers’ practices. To do so, questionnaires, classroom observations and interviews were administered to a number of teachers, school directors, and pedagogical officers in six schools across the country and within the Ministry of Education and Culture. The overall research question addressed by the data collection instruments was: *What assessment practices do Grade 12 teachers in Physics in Mozambique apply and what is their quality?* Specifically, the instruments investigated aspects related to types of assessment practices used by teachers in schools, their quality, and their relevance for classroom practice. Teachers were asked about the types and quality of their assessments. School directors were queried about the purpose and relevance of assessments, as well as the evaluation of the school performance. Educational officers were interviewed to provide information on the relevance of assessments and the level of preparedness of teachers.

The findings indicated that the most frequently used assessment practices in schools are paper-and-pencil tests, verbal tests, and homework, while projects, portfolios, and peer-assessments are the less frequently used ones. These findings further suggest that some teachers have not used some assessment practices mainly because they were not familiar with them and they lacked preparedness for designing and administering them in the classroom. This raises the issue of the quality of assessment practices used by teachers,

which were then dealt with by investigating the frequency of using certain student activities and by analysing the quality of feedback given by teachers to students in paper-and-pencil tests. The quality issue was investigated in terms of the validity of the content of such activities, which included oral communication during lessons, written work, presentations, notebooks, laboratory work, and the student ability to solve problems. The most frequently assessed student activities were written work and the ability of students to solve problems, with laboratory work being the less frequently assessed. The findings indicate that the sharing of the assessment goals between teachers and students, the provision of feedback, and the facilitation of self- and peer-assessment among students are aspects which are hardly considered. The quality of assessment practices was also investigated through analysis of the teacher feedback to students during written tests. The analysis showed that the teachers not only are assessing limited range of student abilities but also are doing this with poor quality. In addition, feedback is not constructive enough to inform further learning.

One of the concerns about the quality of teacher assessment is that, although in the questionnaires a significant number of teachers said they used portfolios, homework, and assessed student ability to solve problems, during the interviews with school directors (who are also teachers) and with pedagogical officers, it became apparent that the teachers did not have either the same or a consistent understanding of these assessment practices. Another weak point of the teacher assessment quality - and thus of its relevance - is the evaluation of the student performance. Engaging students in a reflection about their assessment results meant, for most of the teachers, to sum up the number of students who got negative marks and of those with positive marks and did not involve any formative element of assessment. This suggests that teachers are in need of professional development training in the design, administration and evaluation of assessment practices.

One relevant conclusion of the Baseline Survey is that, although some literature has argued that there are some assessment practices that teachers use successfully (INDE, 2005; Lauchande, 2001), classroom assessment in most of Mozambican secondary schools is, in general, of poor quality. Teachers appear to experience difficulties in designing and

administering most of the researched types of assessments and in addition, the students are not assessed on their ability to perform real-world tasks. As referred to in Chapter 3 (Section 3.6), a performance type of assessment is seen to be one of the most adequate strategies to help students demonstrate their specific skills in applying the concepts and the knowledge they have acquired into real-world situations. According to the literature, an effective performance assessment is most likely to succeed when it is undertaken in a laboratory context where students can perform real demonstration experiments (Airasian, 2000; Dekkers, 1997; Gronlund, 1998; Tamir, 1991; van den Berg & Giddings, 1992). Thus, without neglecting other relevant assessment practices such as observation methods and oral questioning, a choice has been made for this study to improve teacher assessment practices through demonstration experiments where the students are allowed to demonstrate their ability to do real-world tasks while observing all the procedures involved.

Several aspects related to types, quality and relevance of assessment practices are derived from these findings as far as teachers and students are concerned. The ones listed below were of utmost importance and, therefore, were addressed by the Intervention Study.

1. Teachers and students need support in identifying and applying effective assessment approaches

Assessment of student learning of Physics can be a daunting exercise if effective assessment approach is not considered. Despite the importance of laboratory work for Physics learning, findings from the survey indicated that this activity was less assessed by many of the participating teachers. There were a number of reasons for this. Teachers were reported to find laboratory activities too difficult to assess due to the lack of equipment, because of their poor preparation in training institutions, or due to the time needed to conduct them successfully. The intervention phase of this study should suggest an assessment approach that is capable of achieving desirable assessment objectives in the context of the existing conditions.

2. Physics teachers need support in designing and using appropriate and relevant assessment practices

Of the seven investigated assessment practices, two of them (projects and peer-assessment) appeared to be used less by teachers. The reasons for this lack of usage were that either the teachers had no knowledge of that particular assessment strategy or they had a poor understanding about it. Interestingly these two assessments are, according to the literature, some of the most important assessment practices for science education. For instance, Brown et al. (1997) argued that projects have the potential of developing enquiry-based students' skills, which are important for Physics learning. As finished products resulting from a development process, they also bear the potential of developing student abilities for collecting, interpreting and reporting data. In relation to peer-assessment these authors claimed that its power lies on the element of mutuality where students can give and receive feedback from colleagues and teachers, which are important means for student learning. Therefore, the process of improving assessment practices proposed by the Intervention Study should investigate an assessment practice that is associated with these characteristics. This practice, as already argued in Chapter 3 (subsection 3.4.1) is performance assessment. By requiring students to perform real-world tasks, performance assessment, together with the Predict-Observe-Explain strategy of learning and assessment, involves all the elements of enquiry, feedback provision, and assessment of and from peers.

3. Teachers need support in conducting effective formative assessments, especially in conditions of large class sizes

Formative assessment is about the use of learning (or not learning) evidence to improve the teaching and learning. If there is no evidence that students are effectively learning, or if the evidence is not used to inform the next steps in the teaching and learning process, then the process cannot proceed. Findings from the Baseline Survey indicated that the teacher preparedness to conduct formative assessment was poor. Important areas of student strengths and weaknesses were not diagnosed and as a result, the assessment process did not inform the teaching and learning process. The intervention phase of this study should address this problem through producing and making available support

assessment materials containing aspects of formative assessment, particularly in the context of Mozambican education system characterized by traditional styles of teaching and overcrowded classrooms. Teacher training institutions are still dominated by a strong teacher-centred pedagogical approach. So, instead of blaming teachers for the lack of implementation of more learner-centred approaches, it is worth improving the education system as a whole through embedding changes in the training centres. The design of support assessment materials for teachers and students should not only go in this direction, but also toward the suggested idea of introducing ‘exercise books’ for supporting teachers in conducting effective formative evaluation, particularly in the current context of curriculum review. These materials should contain suggestions on how teachers can address the issue of conducting effective formative assessment in the context of large classes.

4. Teachers need support in assessing hands-on students’ activities

This study has chosen Physics as a focus subject. This is an experimental subject by nature and cannot be taught and assessed without practical or laboratory work. Findings from Baseline Survey indicated that paper-and-pencil tests, homework, and verbal tests were the most used assessment practices by teachers. These practices are important and useful for grasping basic Physics concepts but not effective for assessing daily tasks of real-world situations, which are essential for Physics learning. Thus, for an improvement of assessment practices in Physics classrooms, the intervention should support teachers in designing and using assessment strategies that teach and assess the student abilities to observe and interpret phenomena occurring to objects, carry out some hands-on activities, report findings, guided by teachers and teaching materials. So an emphasis on those activities requiring students to develop their manipulative skills, scientific investigation, communication and cooperative skills are important aspects to consider for the intervention to be successful.

5. Teachers and students need support in the evaluation of the student learning

One of the most powerful strategies used to motivate students to learn is to get them involved in the evaluation of their performance. This involvement ranges from sharing

with the students the assessment goals to be achieved, letting them assess themselves and their peers, handing the assessment results out, reflecting with them about the assessment data, as well as explaining the implications of their assessment. Data from the Baseline findings, however, showed that the most common way used by teachers to get the students involved in the evaluation of their performance was reflecting with them about their assessment results in the meaning of only summing up the results based on the pass or fail marks. This implies that the intervention should also support teachers on how can they ensure that students become aware of the importance of their performance by establishing a balance between all aspects of learning evaluation, and on how well the teachers can use the assessment results to inform the teaching and learning process.

In summary, the Intervention Study should address aspects of how teachers can identify, design and use effective assessments as well as how to engage students in some kind of performance tasks. Teachers must also be supported on how to evaluate and report the student work. As argued in Chapter 3, conducting performance assessment (e.g., laboratory demonstration experiments), designing and using exemplary materials (portfolios) and asking students to write laboratory reports, are all activities to be undertaken during the intervention and aimed at addressing the Baseline Survey findings.

CHAPTER 6

IMPROVING TEACHER ASSESSMENT PRACTICES IN PHYSICS IN MOZAMBIQUE

CHAPTER 6

IMPROVING TEACHER ASSESSMENT PRACTICES IN PHYSICS IN MOZAMBIQUE

This chapter reports on the design and formative evaluation of the prototypes of exemplary Physics assessment material (PAM) prototypes in Mozambican secondary schools. The materials are meant to assist teachers in providing formative feedback to Grade 12 students on conducting demonstration experiments and writing a report about these experiments. The chapter focuses on how the prototypes were developed and used by teachers and students in a classroom tryout. Guided by the educational design research approach, the prototypes were developed in an evolutionary and subsequent series of design and formative evaluation steps. The purpose of the tryout was to explore the validity, practicality and effectiveness of the materials. Section 6.1 introduces the chapter, with an overview of the design issues and the importance of the Baseline findings for the Intervention Study. Section 6.2 explains how the first prototype was designed and evaluated, while Section 6.3 presents the design, the classroom tryout and the evaluation of the second prototype. The participants, instruments, data collection procedures, and findings of the tryout are all presented and discussed in this section. The findings are discussed from the teachers' perspective, students' experiences, and researcher's point of view. The teachers expressed their views in relation to the quality of PAM materials in general and on the preparation and execution of the demonstration experiments. Students' experiences are illustrated by the aspects of the experiments they liked most, the aspects that they liked least, and how these demonstration experiments differed from the usual Physics experiments they conduct (if any) in the classroom. Aspects of preparation for classroom tryout as well as students and teachers' difficulties during the execution of the experiments are expressed by the researcher's views. The design and evaluation of the third prototype is presented in Section 6.4. Comments and suggestions from experts in relation to the third version resulting in the fourth version are discussed in Section 6.5 as a final expert appraisal of the PAM materials. Section 6.6 presents the conclusions and implications for further development.

6.1 Introduction

This study is aimed at investigating and improving the assessment practices used by Grade 12 Physics teachers in Mozambique. The literature review (Chapter 3) and the Baseline Survey (Chapter 5) provided background information out of which design guidelines and specifications for the Physics Assessment Materials were formulated. The literature review presented a clear picture of the existing need, both in the African context and elsewhere, to use collected evidence of assessment practices to make decisions about the next steps in learning. Lessons learnt from the review indicate that teachers need support in developing and using exemplary support materials on performance assessments and that these materials: (i) should be designed for an ordinary classroom environment to allow users to participate in the process while working in their normal routine; and (ii) should be formatively evaluated to allow that the learning evidence be used to feed the teaching and learning process. Apart from pointing out that teachers have mostly been using paper-and-pencil tests, the findings from the Baseline Survey revealed also that teachers lack preparation in terms of being capable of designing and administering appropriate assessment practices. More importantly, the survey highlighted the need to support teachers in conducting effective formative assessments, particularly for Science subjects like Physics and in conditions of large class sizes.

This chapter focuses on the design and formative evaluation of exemplary materials on performance assessment through demonstration experiments and a written report by students aimed at helping teachers to improve their assessment practices. The materials are designed and evaluated for the topics of *force* and *inertia*, which is part of Mozambican Syllabus for Grades 11 and 12 students.

Building from the previous chapters and recapitulating what has emerged from them, the following aspects appeared to be vital for the Intervention Study.

1. The literature reviewed in Chapter 3 has emphasised the importance of performance assessment as one of the most important assessment practices in Science education. There are two reasons for this. Firstly, because Physics is an experimental subject, which requires students (and certainly students in the final grade of secondary

education) to demonstrate meaningful application of essential skills and knowledge into practice. Secondly, because Grade 12 is the students' gateway to the employment sector or to higher education and thus they should be assessed on their ability to perform real-world tasks.

2. The intervention studies reviewed in Chapter 3 have highlighted the importance of developing exemplary support materials for teachers. These materials not only help teachers in several aspects of teaching and learning (subject knowledge, lesson preparation, teaching methodology, and assessment and feedback) but also allow students to construct their own knowledge.
3. Findings from Baseline Survey reported in Chapter 5, have shown that teachers were experiencing difficulties in designing and administering basic assessment practices. The findings have also confirmed that students were not assessed on their ability to perform tasks. The analysis of these findings indicated that the teachers not only were assessing limited range of student abilities but also that feedback was not constructive enough to inform learning.

In the Intervention Study being reported in this chapter the three aspects mentioned above are brought together. The improvement of assessment practices, being the purpose of the intervention, focuses on a performance type of assessment (through demonstration experiments) aimed at designing and developing a number of exemplary support materials (prototypes), which contain procedural guidelines for monitoring formative assessment and providing feedback to students. A decision had been made to put more emphasis - especially in the early versions of the exemplary materials - on the quality of the lesson materials for teachers and on the strategies for conducting demonstration experiments by students rather than on the assessment strategies and feedback provision (refer to Chapter 4, subsection 4.3.2.3 and Chapter 5, subsection 5.2.3). The reason for the decision is that for the teachers to be able to conduct effective assessment strategies they need support in preparing lesson materials of good quality. Any assessment strategy can only produce good learning results if this learning is taking place with quality learning materials. However, attention has also been paid to assessment strategies and feedback at the later stage of the intervention (e.g., on the final version of the PAM materials) where a number

of guidelines on how to monitor formative assessment and provide feedback is formulated.

6.2 Design and evaluation of the first prototype

As was referred to in Chapter 4 (subsection 4.4.3), the first PAM prototype contains materials on the topics of force and inertia. Although a correct teaching and learning of Physics content is important (concept acquisition skills), the PAM prototype emphasises the assessment component with focus on how to provide teacher' support in improving their formative feedback on student abilities to perform demonstration experiments.

6.2.1 Design of the first prototype

The first version of the prototype on PAM materials was designed by the researcher following design guidelines and specifications of exemplary assessment materials described in Chapter 4 (subsections 4.4.1 and 4.4.2), which were adapted from design specifications used by similar studies done by Mafumiko (2006) in Tanzania, Motswiri (2004) in Botswana, Ottevanger (2001) in Namibia, Nieveen (1997) in The Netherlands, and Teclé (2006) in Eritrea. As has been stated in Chapter 4 (subsection 4.4.1) these studies focused on supporting teachers by providing procedural specifications on lesson preparation, knowledge of subject matter, teaching methodology, and assessment of student learning. The general format of the PAM materials contained most of these features. A very distinctive element that made this study different from the above-mentioned studies is that the focus is on the design of exemplary assessment materials while the referred studies focused on exemplary curriculum materials. Besides, some additions were made which included a *teachers' guide* with description of the components of the assessment strategy and a *glossary of terms* explaining the key concepts used in the prototype. Applying these design guidelines and specifications, the first prototype of the PAM materials consisted of the sections described below.

- Part 1: *Introduction* - presented the place of the concepts of force and inertia in the Cycle 2 (Grades 11 and 12) Physics curriculum and the target student population.

For the teacher's consideration, an explanation about how to teach and assess the concepts using Prediction-Observation-Explanation (POE) strategy was provided in this part. Both teaching and assessment approaches followed the same strategy.

- Part 2: *Teacher's Guide* – provided an explanation of components and functions of assessment to help the teacher develop her/his own assessment strategies and a practice-oriented teacher's guide containing the sequence of content and lesson plan, some logistical aspects, and a plan of how to teach and assess following the POE strategy.
- Part 3: *Demonstration experiments* - started with presenting five demonstration experiments for students to carry out with a set of procedural specifications for teachers to guide the students when performing the demonstration experiments. This part also presented, as a sixth activity, the demonstration experiment report template for students as a summary of the five experiments, and ended with assessment rubrics to be used by the teachers in assessing student performance.
- Part 4: *Glossary of terms* – provided definitions and explanations of a number of terms or concepts used in the PAM prototype and a number of evaluation instruments (Appendices G, H, I, J, K) used by both teachers and students to evaluate the overall quality of the prototype particularly in terms of the practicality of the prototype.
- Part 5: *Worksheets* - presented the worksheets that the students used to carry out the demonstration experiments. The worksheets are composed of two sections. Section 1 (for individual work) corresponds to the first phase of the POE strategy (Prediction) that the students should do before carrying out the experiment, and Section 2 (for group work) is the second phase (Observation and Explanation), which is the actual demonstration experiment and the reconciliation of the data or outcomes.

Table 6.1 provides an overview of the design specifications applied to the development of the first prototype on PAM materials of this study.

Table 6.1: Design specifications of Physics assessment materials

Area of support	Design specifications
Lesson preparation	<ul style="list-style-type: none"> • General overview of the lesson plan • Description of the intended learning outcomes • Suggestions on lesson plan and timing of the teaching and learning activities • Materials required for the demonstration experiments • Suggestions on how to deal with potential problems that may occur
Subject knowledge	<ul style="list-style-type: none"> • Suggestions for preliminary questions on students' prior knowledge to guide students about the experiments they are going to perform • Short explanations or revision of key Physics concepts • Examples of students' questions and answers
Teaching methodology	<ul style="list-style-type: none"> • Clear description of the roles of teacher and students • Suggestions on grouping of students during experiments • Suggestion on the need to try out the experiments beforehand • Suggestions on how to apply the POE strategy in its three phases
Assessment and feedback	<ul style="list-style-type: none"> • Suggestions on how to assess formatively the different student performance abilities during experiments through using rubrics • Suggestions on how to assess summatively the overall performance of the students using the Demonstration Experiment Report template.

Based on these specifications, five demonstration experiments were designed for lessons of the first prototype. The sixth lesson was reserved for the introduction of the Demonstration Experiment Report template to students. The lessons are presented below.

- **Lesson 1 (45 min)** - *Introduction to force concept*: The POE strategy is used to examine student understanding of the concept of force. The experiment intends to introduce the concept of force by comparing some of the students' common-sense beliefs about it, which are seen to be incompatible with the scientific theory.
- **Lesson 2 (45 min)** - *Investigating the notion of force*: In this lesson, objects are set in motion and the POE strategy is used to explore the aim of the lesson, which consists of remedying the students' alternative conception of impetus.

- **Lesson 3 (45 min)** - *Introduction to Newton's Second Law of motion*: Use of POE strategy to probe students' understanding of the variation of the module of acceleration as a function of varying forces and explanation of the physical significance of Newton's Second Law of motion. The experiment begins with a brainstorm on students' understanding of basic concepts such as force, mass, speed, and acceleration.
- **Lesson 4 (45 min)** - *Investigating inertia using a coin on the top of a can*: The POE strategy is used to introduce the concept of inertia by analysing the behaviour of a coin put on a piece of a card, which is on a milk can.
- **Lesson 5 (45 min)** - *Investigating inertia using a bottle put horizontally on a piece of paper*: The POE strategy is used to demonstrate the effects of inertia. A bottle is put horizontally on a piece of paper, which is on the top of a table.
- **Lesson 6 (45 min)** – *Demonstration Experiment Report*: Explanation of the aim, procedures, methodology, and due date for preparing the Experiment report by students.

Having presented the design specifications, which guided the development of the first prototype, and the experiments to be carried out in the classroom, the following subsection discusses how this prototype was formatively evaluated before classroom tryout in order to improve its validity.

6.2.2 Formative evaluation of the first prototype

The formative evaluation of the first prototype of the PAM materials was undertaken mainly through appraisal by experts and to a lesser extent by users. The reason for this is that the focus of the appraisal was to further explore the validity of the material, i.e., the internal consistency between the prototype and the state-of-art-knowledge on Physics. Some aspects of practicality of the material were looked at by verifying, for instance, whether the usability of the prototype was compatible with the researcher's intention.

The appraisal was made through individual consultation with three groups of education professionals. Firstly, this was achieved through gathering opinions from three experts, namely a curriculum expert from the University of Twente, The Netherlands, a Science education expert from Eduardo Mondlane University, Mozambique, and an assessment expert from the University of Pretoria, South Africa. All experts have ample experience in Physics pedagogy, design and development of curriculum materials, and assessment. Secondly, the prototype was appraised by three postgraduate students from Eduardo Mondlane University who are also Physics teachers at high schools in Maputo. Two of them were involved in developing teacher support materials and in curriculum review for secondary education within the Ministry of Education and Culture. Thirdly, the appraisal was done by four Physics teachers who have more than ten years of teaching experience and who are teaching Physics in schools around Maputo City.

All experts were asked to comment on the overall content, the POE teaching and assessment strategy and on what they thought about the quality of the material in general. The curriculum and assessment specialists looked at a number of the curriculum components and functions referred to by van den Akker (1999) seen from the perspective of assessment. The science education expert was asked to review the quality of the prototype from the subject matter's point of view, i.e., the content accuracy of the two concepts under investigation. To guide their overall appraisal experts were requested to consider the following two questions (see also Appendix F):

a) Are the various items of the prototype accurate and specific enough to convey the intentions of the developer of establishing validity?

b) Is there consistency between the evaluation instruments (Appendices G to K) and the prototype?

Appendices G to K are the evaluation instruments used by university students, teachers and students to evaluate formatively the validity and practicality of the prototype before and after the classroom tryout. The university students and the Physics teachers were

asked to provide their views on the validity and usability of the materials as users. Specifically they were asked not only to provide feedback about the POE teaching and assessment strategy, but also on the teachers and students' potential problems during the activities, and other practical problems linked to carrying out the experiment. Appendices G and H are the evaluation instruments used by university students to guide their appraisal to the prototype.

In general, all appraisers (experts, teachers and university students) were positive about the idea of the PAM prototype. They commented that the content and the level of difficulty of the activities were suitable for the level of the students. However, they observed a number of aspects that needed attention in order to improve the quality of the prototype and made the following suggestions.

- In the wording of the demonstration experiments there is a mismatch between investigating physical concepts, and students' alternative conceptions. For instance, the experiment nr. 1 (*Introduction to force concept*) investigates a 'concept', while the experiment nr. 2 (*Investigating the notion of force*) is about students' (mis)conceptions. There is, therefore, a need to research specific knowledge and address the tasks in a coherent manner.
- An illustration of how the lessons will be conducted and experiments carried out needs to be provided. The teacher should have a practice-oriented lesson plan with all steps to be followed during each experiment.
- All demonstration experiments must be tried out in a real laboratory class environment to ensure practicality of the materials under the existing conditions.
- The demonstration experiments should be planned to fit within the time allocated for Physics lessons in the teachers' timetable (two double periods of 90 minutes, per week).
- With the PAM materials in general, a clear distinction and sound instructions should be given to distinguish between the teachers' guide, meant to help teachers develop their own assessments and the students' worksheet, for the demonstration experiments to be carried out by students.

- The teachers should be made aware that the POE strategy is not only an assessment strategy but is also a teaching strategy.
- The goals of the students' tasks must always be accompanied by corresponding assessment criteria.
- The prediction phase should be made individually to prevent a situation where relatively bright students take the lead in the discussions ahead of the low achievers.
- The assessment components and the glossary of terms sections should be made short enough to allow teachers to use them in a normal classroom environment.

6.2.3 Conclusions and recommendations for improvement

Overall, the expert and user appraisal was instrumental in improving the validity and some aspects of practicality of the Physics assessment materials by generating valuable suggestions for improvement. In general, all relevant suggestions were incorporated into the second prototype. Furthermore, in terms of the duration of lessons, the teachers have suggested that it would be more realistic and practical to have two time slots of 90 minutes each instead of the suggested three. This reduction in time did not raise any problems because, as a result of the suggestion given by the appraisers, the experiment nr. 2 (*Investigating the notion of force*) was removed and not included in the tryout. In the end, the number of experiments was reduced from five to four. Teachers also suggested that the introduction of the template for the experiment report could easily be given at the end of the last experiment and therefore does not need a separate time slot.

6.3 Design and evaluation of the second prototype

This section presents the design of the second prototype and the evaluation focus and questions, the selection of participating teachers and students, and the evaluation instruments for the classroom tryout. The design of the second prototype is presented in subsection 6.3.1. The description of the participants, the characteristics of the evaluation instruments and the procedures are all presented in subsection 6.3.3. Subsection 6.3.4

provides the findings of the classroom tryout, while the findings from the formative evaluation of the second prototype are provided in subsection 6.3.4.

6.3.1 Design of the second prototype

The review of the first prototype was the first cycle of formative evaluation and the comments and suggestions were taken into account in the design of the second version of the prototype, which was used in the classroom tryout. The second version of the prototype on PAM materials was also designed by the researcher following suggestions and comments from experts, teachers and university students. Adaptations and additions made to accommodate the suggestions from appraisers included those listed below.

Length of sections: The explanations of components and functions of assessment (Teacher's guide section), which initially included ten assessment components, and the definition of concepts or terms (Glossary of terms) were made short in order to be user-friendly for teachers. As a result, the teacher's guide in the second prototype had five assessment components (see Chapter 4, subsection 4.4.3). A practice-oriented lesson plan was included to help teachers guide the demonstration experiments.

Content: The wording of the experiments was improved to avoid confusion between investigating physical concepts and discussing students' alternative conceptions (see Table 6.2). As a result, experiments nr. 3, nr. 4, and nr. 5 were reformulated and the section about the demonstration experiment report was embedded in the second time slot of 90 minutes.

Execution of the demonstration experiments: As a result of the suggestions made particularly by teachers, handouts of the initial phase of the POE strategy (prediction) were prepared and distributed to students in separate sheets from the other two phases (observation and reconciliation) to avoid giving away the reasoning and the answers to the questions that students were supposed to provide after performing the demonstration experiments.

In summary, the section on demonstration experiments for the second prototype was composed of four experiments distributed into five lesson periods. Table 6.2 summarises the lessons, the content, and the periods of time for each lesson.

Table 6.2: Summary of lessons for the second prototype

Lesson	Summary of the content	Time and periods
1	Introduction to the force concept: The objective of this experiment is to introduce the concept of force. In order to help students understand this concept the POE strategy is suggested, which allows them to compare their common-sense beliefs with the experimental results (scientific theory).	90 minutes
2	Newton's Second Law: The objective of this experiment is to understand the concept of force. The main part of the experiment includes the student understanding of variation of the module of acceleration as a function of force. The relevance of the experiment is that it creates a situation of a moving object with a constant speed. Students are asked to read the forces measured by spring balances and calculate the resultant forces.	
3	Introduction of the concept of inertia 1 - A coin on top of a can: The objective of this experiment is to understand how inertia can be realized through analysing the behavior of a coin put on a piece of a card, which is on a can. By using the POE strategy, you are firstly required to predict what will happen to the coin if the card is flicked quickly, then to perform the experiment yourselves (in groups) and finally to draw a reconciliation between the prediction and observation.	90 minutes
4	Introduction of the concept of inertia 2 – A bottle on a paper: This experiment is about demonstrating the effect of inertia. The bottle is put horizontally at rest on a piece of paper, which is on the top of a table. You are required to realise that after flicking quickly the paper, the bottle tends to stay at rest. Again, the POE strategy is used to assess your understanding of inertia.	
5	Demonstration Experiment Report: Explanation of the aim, procedures, methodology, and due date for preparing the lab report by students.	45 minutes

Lesson three of this prototype is given here as an example of a plan for demonstration experiments following the POE teaching and assessment strategy. With the exception of the lesson on Demonstration Experiment Report, all other lessons of this and other subsequent prototypes followed similar planning structure. In order to illustrate the

characteristics of the PAM materials, the execution of this lesson by the teacher and the corresponding student worksheet are presented in Figures 6.1 and 6.2, respectively.

Figure 6.1: Execution of the lesson: a practice-oriented lesson plan for the teacher

Lesson 3: Introduction of the concept of inertia 1 - A coin on top of a can

Objective of the lesson

The objective of the lesson is to introduce the concept of inertia using the experiment of a coin put on a piece of a card. The lesson intends to illustrate that a coin put on a piece of a card, which is on the top of a can, remains on the top of the can even after the card is flicked away.

Intended learning outcomes

During the experiment students should be able to understand (by observing and explaining) that, because of inertia, the coin remains on the top of the can, when the card is flicked quickly. Students should be assessed towards:

- realising the difference between flicking the card quickly and flicking it slowly as this is important for the explanation of the concept of inertia.
- explaining the reasons behind the behaviour of the coin.

The teaching and assessment strategy to achieve this is characterised by (i) allowing students to predict what will happen to the coin put on a piece of a card if the card is flicked quickly (individually); (ii) letting them perform the experiment themselves and observe the behaviour of the coin (in groups); and (iii) asking them to draw the reconciliation between their predictions and what they actually observed during the experiment (individually).

Lesson plan and timing

Activity	Approximate time (in minutes)
Start of the lesson	5
Activity: Experiment	
-Prediction	10
-Experiment	15
-Reconciliation	10
Assessment and feedback	-
-Monitoring	
-Providing feedback	

Conclusion and end of lesson	5
Total	45

1. Start of the lesson (maximum 5 min)

You may start the lesson by asking students brief questions on what they already know about concepts like force and mass. A small discussion about these concepts may help you to understand and evaluate student predictions and/or their responses during experiments. Examples of the questions to get the discussion started are:

- What do you understand about force?
- What do you understand about mass?
- (Other questions...)

Having had a number of responses to these and other questions and having facilitated the discussion:

- State the objectives of the lesson (emphasising the POE strategy) and clarify what is intended to be achieved at the end of the experiments.
- Explain the working method: everyone must be in the classroom and they must be organized into groups of a maximum number of four students each.

2. Activity: demonstration experiment

(i) Prediction (maximum 10 min)

Start the experiments by forming the groups and its distribution in their places. First distribute the first part of page 1 of the students' worksheet (about prediction) to each student. Guide the students in doing part 1 of the POE strategy (prediction) individually.

- While the students are looking for answers to the questions posed on the prediction section, help them to do the reasoning, but only as a moderator!

(ii) Experiment (maximum 15 min)

- Distribute the necessary material for the demonstration experiment: A coin, a piece of a card, and a can. Assign students in groups of two or three and give each group the remaining part of the students' worksheet. Ask students to have pencils and sheets of paper for calculations.
- Ask students to perform the experiment in groups following the steps indicated on the Student Worksheet.
- While they are doing the experiment and answering the questions posed in the observation section, keep helping them doing the reasoning, but only as a moderator!

(iii) Reconciliation (maximum 10 min)

Guide students on how to compare and explain consistencies or lack of them between results from the prediction and from the observation, but only as a moderator!

3. Assessment and feedback (to be considered throughout the lesson)

You must undertake a formative evaluation of the students' work through:

- starting the lesson by asking brief questions to students on what they already know about force, speed, mass, or inertia;
- verifying whether the students understood the outcome to be achieved at the end of the experiment, and procedure (teaching and assessment methodology) to be followed to achieve this;
- observing what students do (individually and in groups). During the experiment you should ensure that the coin is put on the top of the can adequately and that the card is flicked away quickly. Whenever possible, you must also ask probing questions (e.g., why should the card be flicked quickly?);
- encouraging students to discuss amongst themselves (during the experiment) several aspects of the experiment. For instance, ask them to explain why the coin does not remain on the top of the can when the card is not flicked quickly;
- allowing students (during the reconciliation phase) to reflect on differences or similarities of their predictions and on those observed during the experiments and allow comparisons between their ideas with those of their colleagues.

Remember, your role is to facilitate the students' work, and should act only as a moderator.

4. Conclusion and end of the lesson (maximum 5 min)

You may round off the lesson by recapitulating its objective, that is, to understand why the coin put on a piece of a card, which is on the top of a can, remains on the top of the can when the card is flicked away quickly. Whenever time allows, ask some individual revision questions to verify the extent to which the intended learning outcomes have been achieved. Give students immediate congratulatory or critical feedback (preferably individual). Explain also the students that they will have to evaluate and summarise their answers and observations about the laboratory experiment. Tell them that this will be done by the means listed below.

- Writing Demonstration Experiment Report - distribute the Report template and urge them to meet the deadline for submission.
- Filling in an Evaluation Experiment Questionnaire - this is to be given immediately after performing the last experiment.

The type of information to be asked in the Demonstration Experiment Report and in the evaluation questionnaire and how to assess it is provided in the PAM assessment materials (Appendix P).

Round off the lesson by asking students to clean up and return the materials used in the experiment.

Figure 6.2: Worksheet for students

Experiment nr. 3: Introduction of the concept of inertia 1 - A coin on top of a can

The objective of this experiment is to teach inertia through analysing the behavior of a coin put on a piece of a card, which is on a can. By using the POE strategy, you are firstly required to predict what will happen to the coin if the card is flicked quickly, then to perform the experiment yourselves (in groups) and finally to draw a reconciliation between the prediction and observation.

3.1 Equipment required:

- (a) A coin
- (b) A piece of a card
- (c) A can

3.2 Prediction:

A coin is placed on a piece of a card, which is on a can. If the card is flicked quickly the coin:

- (a) will be dragged off with the card
- (b) will stay where it was (on the top of the can)
- (c) other: _____

Give reasons for your prediction:

3.3 Observation (experiment):

In groups of three students each, perform the following experiment:

Place a coin on a piece of a card on the top of a can, as shown in Figure 2. Flick the card quickly.

Describe your observation.

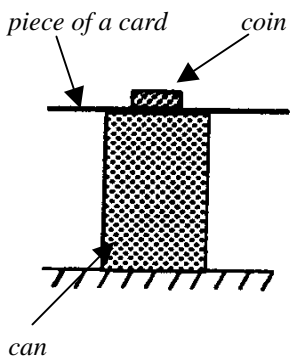


Figure 2: A coin on top of a can

Repeat the experiment twice. Describe what you observe regarding what is happening with the coin.

Explain why_____

3.4 Reconciliation between prediction and observation:

- (a) Compare the results of the prediction and those of the experiment.
- (b) Are the results of the experiment the same as those of your prediction? (Yes)____/(No)_____.
- (c) Justify your answer_____

Subsection 6.3.2 discusses how the second prototype of the PAM materials was evaluated before the classroom tryout.

6.3.2 Evaluation design of the second prototype

The main objective of the tryout of the second prototype was to find out whether the PAM materials developed, appraised, and tried out with and by teachers in the Mozambican context were already practical and effective for the Grade 12 level Physics classes. Based on the findings from the Baseline Survey and with this objective in mind, the evaluation of the second prototype was designed. The initial step consisted of the identification of a number of topics which was used to guide the formulation of the main evaluation questions. This was followed by the formulation of the main evaluation questions which were the basis for developing the evaluation instruments for both teachers and students. The main evaluation question for the teachers was formulated as follows:

- *What are the teachers' opinions about the use of PAM materials and their experiences with student performance assessment in the demonstration experiments?*

For the students the evaluation question was formulated as follows:

- *What did the students like and dislike about the demonstration experiments?*

These questions were then used for elaborating the sub-questions in the data collection instruments for teachers and students. Some examples of the aspects dealt with in the

evaluation sub-questions included the clarity of language, the description of the experiments, the practicality of the POE strategy, the role of teachers and students during formative assessment, and the time required to carry out the experiments following the POE strategy. Table 6.3 provides an overview of the sub-questions posed to each of the users.

Table 6.3: Overview of the sub-questions for the evaluation design

	Elements of typology	Sub-questions
Teachers	General impressions about the material	<ul style="list-style-type: none"> • Is the language clear and understandable for students? If not, explain what the problems were. • Was the description of the demonstration experiments and pictures clear for the students or did they have many questions? If not, what are the needed improvements? • Do you feel the prototype as a whole needs any changes or additions? If yes, what changes?
	Opinions about the demonstration experiments	<ul style="list-style-type: none"> • Was the POE strategy of teaching and assessment practical for students' reasoning? <ul style="list-style-type: none"> ○ Which parts were useful and why? ○ Which parts need improvements and why? • What was your role as a teacher during the experiment? • Do you feel that the main objective of these demonstration experiments will be achieved? If not, which particular aspects will not be met and why?
Students	Opinions about the demonstration experiments	<ul style="list-style-type: none"> • What is your impression about the structure of the material? • What did you like and dislike about the demonstration experiments?
	Experiences concerning differences between demonstration experiments and the usual Physics experiments	<ul style="list-style-type: none"> • Were the demonstration experiments different from the usual Physics experiments you are used to in your class? • What was your role as a student during the experiment? • Did you face any problems during the execution of the experiments? If yes, what were the problems?

Apart from any practical problems that teachers and students could identify during the classroom tryout, the evaluation also addressed two aspects from the researcher's perspective. Firstly, the researcher's focus was on those aspects where teachers seemed to experience difficulties during preparation of the demonstration experiments. Secondly, the emphasis was on those aspects that could be regarded as problematic for both teachers and students during the execution of the experiments. This information was collected by the researcher using a logbook.

In summary the sub-questions shown in Table 6.3 (first column from right) were used as questions to guide the designing of evaluation instruments. The sub-questions addressed the two main evaluation questions from four perspectives, namely: (i) teachers' general impressions about the Physics assessment materials; (ii) teachers' and students' opinions about demonstration experiments following the POE teaching and assessment strategy; (iii) students' experiences concerning differences between demonstration experiments and the usual Physics experiments; and (iv) researcher's general impressions, opinions and experiences about the course of the demonstration experiments.

Subsection 6.3.3 discusses how the second prototype of the PAM materials was tried out in the classroom.

6.3.3 Classroom tryout

The second version of the prototype was tried out in the classroom by two teachers and their students (n=62) from Joaquim Chissano Secondary School in Gaza Province and from Matola Secondary School in Maputo Province. Four demonstration experiments were tried out in the classroom. This version had taken into account comments and suggestions from the appraisal of the first version done by experts and the postgraduate students. The main objective of the tryout was to identify initial problems with the *practicality* of the PAM materials in the context of Mozambican Grade 12 level Physics classes. More specifically, the tryout was intended to find out whether the materials have

the potential of being successfully used by teachers and students following the POE teaching strategy.

The following subsections report on the characteristics of participants, the type and characteristics of the data collection instruments, and the procedures followed during the classroom tryout.

Participants

The tryout was undertaken in two public and urban secondary schools from Gaza and Maputo Provinces. Participants were two Physics teachers and 62 Grade 12 students from the science stream. The schools are here referred to as school 1 and school 2, while teachers are indicated as T1 and T2. Table 6.4 provides a summary of the characteristics of participants in the classroom tryout of the second prototype.

Table 6.4: Characteristics of participants of the classroom tryout

Participants	School 1	School 2
<i>Teachers</i>	T1	T2
-gender	-Male	-Female
-professional qualification	-Licenciatura	-Licenciatura
-teaching experience (years)	-10	-12
-other responsibilities	-Subject leader	-None
<i>Students</i>	Class A	Class B
-number	21	41
-age-range	17-23	16-21

In total, about 67 participants tried out the materials. Sixty-two (13 girls and 49 boys) Grade 12 Physics students from the two schools, their two teachers (one from each school), and three other teachers from the Francisco Manyanga Secondary School who were invited to participate in a one-day evaluation workshop together with the teachers from school 1 and school 2. The workshop was meant to train the participating teachers in using the assessment materials, with an emphasis on their application and utilisation (functions of assessment relevant for Physics, sequence and content of lesson periods,

preparation and execution of lessons, etc.). The two teachers who took part in the tryout had *licenciatura* degrees, a five-year teaching course in Physics and mathematics and each had more than 10 years of Physics teaching experience. Teacher T1 was also responsible for coordinating the subject for the grade in his school.

Instruments

The instruments used for the tryout were designed on the basis of the analysis of the evaluation design (refer to Table 6.3) and thereafter adapted from the instruments used in similar studies by Mafumiko (2006) and Tecle (2006). They included an evaluation questionnaire and interview schedule for teachers (Appendices I and J), a student questionnaire (Appendix K) and a researcher's logbook. Characteristics of these instruments are presented below.

Teacher questionnaire and interview schedule

Both teachers individually completed a questionnaire at the end of all sessions with Physics demonstration experiments. The questions in the questionnaire focused on the teachers' general opinions about the experiments in terms of relevance of the topic, content, structure of the teaching strategy, and presentation of the experiments. The questions also included aspects related to potential problems with the availability of time to carry out the experiments, other practical problems linked to experiment execution, and teachers' suggestions on how to improve and adapt the teaching strategy in their classes. Following on from the questionnaire and based on their results, a follow-up open-ended interview with the two teachers was conducted to elicit information and provide clarification on some aspects from the questionnaire. The teachers' questionnaire and interview schedule can be found in Appendices I and J.

Student questionnaire

All 62 students from the two schools completed a semi-structured questionnaire at the end of all demonstration experiments. The questionnaire was meant to discover the opinions and experiences of students of the demonstration experiments they conducted. The focus was on what the students liked or disliked most, the specific learning activities, and how

the lessons compared to their regular Physics demonstration classes. For more information about this questionnaire see Appendix K.

Researcher's logbook

As referred to at the beginning of this subsection, the researcher used a logbook to keep a record of activities and observation notes linked to the use, by both teachers and students, of demonstration experiments and Physics assessment materials in general. The focus was on those areas where teachers seemed to experience difficulties during the preparation of the experiments. For the execution of the experiments, the researcher kept running notes on how teachers introduced the POE strategy, and how they monitored the student activities and the assessment process. Notes were also kept on the observed responses of students to performing Physics experiments and any difficulties they experienced.

Procedures

As a preparation for the classroom tryout, the researcher distributed copies of the PAM materials (the second version of the prototype) to the teachers a week before the tryout (after the evaluation workshop) for preliminary reading. Four demonstration experiments were conducted in the tryouts in each school. The tryout process consisted of an interactive preparation session (a half-day workshop) with teachers and the researcher at each school to introduce the materials, the purpose of the study, and clarification of potential difficulties in understanding. During this session the demonstration experiments were also tried out in advance with the teachers and copies of the student worksheets were given to the teachers for preliminary reading. The following subsection describes how the demonstration experiments were undertaken in each school.

School 1

Three days in a row were spent in this school during the tryout. The first day was devoted to the interactive and preparation session for introducing the materials to the teacher. The second day was for the tryouts, i.e., for conducting the lessons with the students. The four demonstration experiments were conducted during one block of 90 minutes (consisting of two lessons of 45 minutes) by the teacher, with the researcher as participant observer. Two

experiments were conducted in each lesson of 45 minutes. The teacher conducted the four experiments in one of his classes. The third day was initially dedicated to the completion of the evaluation questionnaire by the teacher and by students. Then a general discussion with students about the experimental results and the difficulties they encountered in carrying out experiments using the POE strategy, was held. Thirdly, and following the discussion, the students were given the laboratory experiment template to take home and to use for writing the report. They were urged to submit the report within one week. Finally and by the end of the day, the teacher was interviewed to find out his views about the experiments in general and of the practicality of the materials overall. In particular, the teacher was asked to express his views on students' formative assessment, the impact of the laboratory report on students' assessment, and the practicality of the POE strategy.

School 2

At this school the same number of days as in school 1 was spent following the same procedure. The preparation session took place during the first day between the teacher and the researcher. Teacher T2 conducted the four experiments during two lessons. The experiments were all co-supervised by the researcher as a participant observer. The last activity involved administering the evaluation questionnaires to students and to the teacher, as well as interviewing her with the aim of gathering her experiences and opinions about the materials.

As referred to earlier on, the purpose of the second tryout was to increase the practicality of the PAM materials from users' feedback in the context of classroom environment. Teachers and students were asked to conduct the experiments and to use the PAM materials as prototypes, i.e., not as final products, but as products which might require improvements. Therefore, flexibility in adapting the materials and encouragement to provide alternative ideas whenever needed were allowed, always paying attention to the POE strategy, the performance assessment task, and practicality of the materials.

Subsection 6.3.4 reports findings of the classroom tryout.

6.3.4 Findings from the classroom tryout

The classroom tryout focused on the *practicality* of the PAM materials, particularly the use of POE strategy. The emphasis was on: (i) how the demonstration experiments were conducted in class; (ii) how teachers felt about using the materials, following the strategy and monitoring the experiments; (iii) what the students experienced about the experiments following the POE strategy; (iv) what teachers and students' conceptual difficulties were with the materials and experiments as seen by the researcher; and (v) what lessons could be learned from demonstration experiment reports written by students and evaluated by the teachers. The following subsections present and discuss results of the classroom tryout.

Teachers' impression about the PAM materials and their opinions on the experiments

Teachers' opinions about the PAM materials and demonstration experiments are discussed from two perspectives. Firstly, the focus is on how practical and effective the materials can be as teaching and assessment tools. Secondly, the emphasis is on the contribution of these materials – particularly the POE strategy – to the students' understanding of Physics concepts.

The general impression of the two participating teachers about the practicality and effectiveness of the PAM materials was positive. They indicated that materials of this nature would be very useful in helping them, firstly, to enhance their professional experience and secondly, to prepare their own assessments for students. For instance, they liked the presentation and structure of the materials following the POE strategy, and felt that this helped students to construct their own understanding of the concepts as advocated by the constructivist approach and recommended by the Grades 11 and 12 Syllabus. Teacher T1 for instance, referred to the fact that, in his role as subject leader, he had been facing demands from colleagues to provide support in lesson preparations particularly with guidelines on how to design and facilitate appropriate demonstration experiments. This teacher commented that, although his school had some laboratory equipment, most of

his colleagues seemed to be ill-prepared to carry out laboratory lessons apparently due to their poor preparation. This situation “seems to be more acute for those teachers who were trained many years ago and who, despite their long teaching experience, appear to be in more need of support than their younger and newly trained colleagues”, said this teacher. Besides this positive impression about the materials, the teachers also raised some concerns. For instance, the fact that the POE strategy is principally more suitable for the introduction of new concepts and motivational phases of teaching rather than for lessons aimed at consolidating already acquired concepts or knowledge, was referred to by teachers as one aspect that could be taken into account in future. Table 6.5 summarises teachers’ general impression of, and comments about, the improvement on the practicality and effectiveness of PAM materials.

Table 6.5: Teachers’ general impression about the second prototype of the PAM materials

Aspects of the material		Teacher 1	Teacher 2
General impression	Language	Understandable for the level of the students.	Very clear, provided that some related concepts be introduced to students well in advance.
	Description of the demonstration experiments	Very well structured, fall under prescribed G12-level, clear instructions and easy to follow. Materials available locally. But in experiment nr. 2 better talk about <i>average speed</i> .	Content very well presented, experiments well explained but some related concepts need to be explained in advance (e.g., measurement error).
	Pictures	Clear and neat, except the picture of experiment nr. 2	Picture of experiment nr. 2 need to be improved
	Teachers’ guide	Useful but too long to follow. It is difficult to get time to read the entire guide prior to designing of each task.	Very relevant for Physics teacher, well structured and understandable provided the glossary of terms.
	Time management	Difficult with so many students in the class. Ninety minutes would be enough for only four experiments.	Time could be a serious problem given our overcrowded classrooms. Maybe it would be desirable to conduct experiments during extra time periods.
	Relevance and usability	Very useful and relevant for G12 students. The experiments provide students with opportunity to think, observe, perform tasks, and discuss the results.	Very helpful, especially for introducing new concepts.
POE strategy	Practicality of the strategy	Very practical: Materials available or obtainable at a reasonable price. Only time would be problematic.	Good strategy, easy to follow but time consuming. It requires students to think and reason about the events.
	Role of the teacher	The strategy is new for the students and my role was mainly to explain students how to follow the steps of the strategy.	My role was to try out the strategy in advance and to guide students during the experiments.
	Students’ involvement	Students were very fascinated with the experiments and this was because I think they thought it was a preparation for the upcoming final exams.	The students seemed to like the demonstration experiments especially because we rarely do experiments like these in our school
	Achievement of the main objective	The objective was achieved. Students seem to understand these concepts very well now.	The main objective was achieved provided that the suggested improvements will be taken into account, especially with the experiment nr. 2.
	Suggested improvements	The time issue must be taken care of. The teachers’ guide also seems to be too long.	Improvements have to be made on experiment nr. 2 (pictures and wording), and the number of experiments should be reduced to fit the timetable.



The table indicates that both teachers considered the PAM materials very useful for Grade 12 students. The materials were found to be helpful for students because they provided them with the opportunity to merge what they have acquired theoretically with experimental practice. Teachers stated that the POE strategy provided a solid foundation for how to design and conduct demonstration experiments. Predicting the results of the events, carrying out the experiments, and observing and explaining the outcomes of the experiment would help students to identify and minimise their own misconceptions about force and inertia. On the practicality of the strategy, both teachers expressed satisfaction with the availability of materials required for the experiments as illustrated by the following response given by teacher 1:

“When I received the copy [of the PAM materials] I did not expect good results because students are not used to conducting demonstration experiments... I was anticipating problems especially in reconciliation of theory and practice... However, this POE strategy is so simple, clear, and well structured that it was easy to follow. But, as I have said before, time can be a problem.”

From this statement it seems that teachers regard the POE strategy as practical for Physics teaching and learning in the classroom and that it can lead to good student results, although it is not explicitly indicated how. The fact that this teacher did not mention the problems that he had anticipated does not allow one to draw relevant conclusions about the potential of the strategy seen from this perspective. Apparently, the problems are linked to the unfamiliarity of students with demonstration experiments or to the students’ inability to provide sound arguments about similarities or differences between their predictions and their observations.

As for their roles as teachers, the findings indicate that they spent most of the time trying to help students in following the steps of the strategy because this was also new for them.

When teachers were asked how they perceive the contribution of the materials to the improvement of student learning, they referred to the pedagogical element of the POE strategy. According to them, the strategy helps to sharpen the students’ levels of comprehension of the concepts of force and inertia. They mentioned the example of the experiment nr. 1 (*Introduction to the force concept*) as most illustrative. While

some of the students predicted that three forces (force of gravity, force of the ‘kick’ and force of air resistance) were acting on the ball during its flight, in the reconciliation phase, where they were involved in discussions amongst colleagues, they were able to amend their thoughts. During the sharing of ideas, it emerged (the students remembered each other) that the experiment was undertaken in an idealised system where the force of air resistance is neglected. It was also during the reconciliation phase where the students realised that during its flight, the ball is no longer under influence of the force of the ‘kick’. In fact, and according to teachers, in this specific demonstration experiment the observation phase was not as effective because students were unable to observe the kind of forces acting on the ball directly. This phase had a rather more instructional effect in the other experiments where events were more directly observable. So, the potential of the POE strategy lies on the possibility given to students to contribute their ideas and enhance the building of knowledge. If students do not engage in such discussions, they do not get the possibility to develop their critical thinking through learning by their own mistakes and those of their colleagues.

Responding to the question of whether there were students who were not active during the experiments, the two teachers indicated that all students were very active. However, the teachers gave different reasons for the active students’ involvement. While for teacher 1 the students were very active because the experiments took place closer to the examination period (and therefore they thought would give them hints for the examinations), teacher 2 felt that this could be because they were experimenting with something new in their school life. Demonstration experiments had not been carried out in school 2 for the whole year.

The two teachers also indicated some aspects that they did not like about the POE strategy and the experiments. The most worrisome of them all is the time spent in performing the experiments. They suggested reducing the number of experiments per lesson or extending the time allocated for the lesson to fit the time needed for each experiment. To solve the problem of the time, the teachers were of the opinion that students should be given the worksheets well in advance to read before they actually arrived in the class. Still according to the teachers, this problem of shortage of time did not allow them to realise at what extent the POE strategy would have facilitated the

students' understanding of force and inertia concepts because the students lacked sufficient time to discuss their views amongst each other and to build informed consensus. Teacher 2 indicated that she did not like experiment nr. 2 because the pictures were misleading and the wording used to explain the several steps was confusing.

Teachers' experiences on conducting demonstration experiments

The teachers' experiences, related to how demonstration experiments were conducted, are expressed by findings obtained through teacher evaluation questionnaire (Appendix I), follow-up interviews (Appendix J), and the researcher's logbook. These data collection instruments focused on two distinctive characteristics, namely the teachers' general impression concerning several aspects of the materials and their opinions about the POE strategy.

Before elaborating on teachers' experiences related to the experiments, it is important to refer that, as was discussed earlier, as a preparation for the classroom tryouts a half-day workshop took place with each teacher as a preparation session prior to the experiments. During this workshop each teacher had an opportunity to clarify potential difficulties with the PAM materials in general (refer to Appendix P), with emphasis on the components and functions of assessment considered relevant when assessing Physics concepts, the sequence and content of lesson periods, and the preparation and execution of the lesson (Part 2, subsections 1 to 3). Teachers' impressions about the quality of the PAM materials in general were presented in the previous subsection. The present subsection discusses the teachers' experiences related to the preparation for and execution of the demonstration experiments.

Teacher 1 felt that the preparation of these experiments took a large amount of time, which is not always available in the normal time schedule. The teacher is of the opinion that teachers' commitment is crucial, if good results are to be achieved from the experiments. In fact, during the preliminary tryout, this teacher spent about 35 minutes in lesson preparation: ten minutes looking for the equipment, fifteen minutes trying out each experiment, five minutes grouping the students, and another five minutes introducing the task to the students. This amount of time is considered to be



large if taking into account that the lessons are placed one after another on the teaching timetable.

Teacher 2, although she also raised concerns about the time needed for preparation, said that this problem could still be overcome with more practice. She argued that preliminary preparation and practising by the teacher could contribute in saving the time. For this teacher the most worrisome problem was the large number of students in the class. She is of the opinion that the POE strategy required a step-by-step guiding of students that was not easy for her with eight groups of about five students to be monitored at the same time.

Effectively both teachers agree on two aspects that need to be considered for the improvement of the demonstration experiments: the time spent during preparation and the management of the class during the execution of the experiments. In relation to the time, the classroom tryout revealed that at least 10 to 15 minutes were used to set up the experiments before the lesson actually starts. However, the normal timetable, characterised by lessons conducted one after another after or following lessons of some other subjects, does not allow such time flexibility. Concerning class management, the problem lies on the large number of students per class. In order to get all students involved in the experiments, class A in school 1, which was comprised of 21 students, had to be grouped in four groups of four students each and a fifth group with five students. The number of groups and that of the students per group was even higher in school 2, where the class consisted of 41 students. Seven groups of five students and one group of six were formed in this school. It was, therefore, difficult for the two teachers to monitor all the groups at the same time in terms of providing relevant guidance and feedback for all students. As a result, teachers became mere explainers to all the students, rather than concentrating on guiding those with difficulties. Some of the most active students were indeed leading the discussions during the experiments but a significant number of other members of the groups, especially the low achievers, were passive and very dependent on the others.

Students' opinions about the demonstration experiments

Students' experiences and views about classroom tryout conducted by way of demonstration experiments were obtained through the students' questionnaire

(Appendix K) and the researcher's logbook. Two themes are used to present the findings on students' opinions about the experiments, namely aspects of the experiments students liked most, and aspects that they liked least.

(a) Aspects of the demonstration experiments students liked most

The overall results obtained from the questionnaire indicated that the students' experiences with the demonstration experiments, like those of the teachers, were positive. The majority of students liked the demonstration experiments, especially the three steps of the POE strategy, namely prediction, observation and explanation. They indicated that they were very fascinated by the way they were able to realise their misconceptions during the experiments and, based on the observation, to develop their own explanations of the discrepancy between prediction and observation of the events, and to draw informed conclusions. The following comments illustrate some students' reactions to the experiments. The comments are grouped in terms of (i) how students felt about learning Physics and (ii) how they perceived the usefulness of the POE strategy including their sense of enjoyment towards the demonstration experiments.

Learning of Physics

Under the aspect of how students perceived that the demonstration experiments can help them learning Physics better the following extracts can be quoted.

- *“I liked most the experiment nr. 2 because I was able to personally analyse in depth the experiment and to draw the conclusions on my own”.*
- *“I felt like a great physicist when I realised the differences in accelerations of two blocks made of the same material and in which are exerted two equal forces”.*
- *“On the experiment about the ball [experiment nr. 1], I was very surprised to realise that there are many forces acting during the entire flight of a ball kicked down. I did not know why the ball was taking long to come down when kicked into the air”.*

From one perspective these extracts show that the students' understanding of Physics concepts was enhanced in the sense that it was possible for students to develop an understanding and to realise the existing interconnections between force, mass, displacement, speed and acceleration. For instance, it is evident from the second extract that, at least, this student has grasped the main idea of the experiment which

consisted of showing the variation of the module of acceleration as a function of force and the possibility to introduce the concept of inertia via the Newton's Second Law. However, from another perspective, these students' comments indicate that the demonstration experiments not only contributed to enhancing the students' understanding of Physics but also to uncover some common-sense beliefs about force and other related concepts, which seems to exist amongst students. For instance, analysing the last extract (about experiment nr. 1) it can be realised that students did not attend to the fact that the experiment occurs in an idealised system (as prescribed in the Grade 11 and 12 Physics Syllabus) where the force of air resistance is neglected. Rather, they are considering a normal system and they are interpreting the interaction of forces as a struggle between many (not necessarily opposing) forces. It appears for students that the ball takes a while to come to rest because of the number of forces acting upon it. According to the literature this could be seen as some kind of students' common-sense beliefs following from a metaphor that 'a win go to the stronger' (Hestenes et al., 1992). Still according to these authors, for the students, the ball is taking long in the air because forces are still 'fighting' and it will only come at rest when the stronger wins. They do not see the time spent by the ball during the entire flight as a result of the magnitude of the kick that can produce a smaller or bigger reach of the ball (X_{min} or X_{max}). This, in turn, can lead to some kind of 'dominance principle' according to which the most active agents produce the greatest forces. If this students' interpretation prevails it can hinder the students' understanding of the Newton's Third Law of motion based on action/reaction pairs.

Usefulness of the POE strategy and enjoyment of the experiments

The extracts below can be quoted on this respect.

- *“Starting any experiment by making your own prediction of the event is so fascinating that you never forget the results of the comparison [reconciliation] ... even if your thoughts are not equal to the outcomes of the experiment. This is what I liked most about the experiments”.*
- *“I liked most the reconciliation between my own thinking [prediction] and the practice [observing the actual experiment]. After the experiment I was able to evaluate my own mental ability”.*



- *“I enjoyed doing practical by myself and using locally available material. For instance, the experiment about ‘the piece of a card put on the top of a can’ was so real and in my group we had a heated debate because it was about something happening in our real life”.*
- *“On the experiment about the bottle [experiment nr. 4], it was so fascinating to see the bottle remaining at rest on the top of the table even with the paper being flicked away”.*

These extracts reveal that students felt the usefulness (including practicality) of the POE strategy, particularly the importance of making predictions. They seemed to realise that predicting means drawing upon relevant observations and data and saying something about a future of an event, even if that prediction does not necessarily coincide with the actual observation. This is indeed crucial for the POE strategy because it raises the students’ awareness and understanding of the process itself rather than the outcome.

The second extract shows also how students can improve their own reasoning by discussing and comparing (during reconciliation) their ideas with those of their colleagues. These comments also reveal the students’ positive attitude towards Physics demonstration experiments, with emphasis on the element of the student self involvement and manipulation of equipment. They enjoyed being involved in the experiments themselves and developing their own understanding of the physical phenomena. The fact that students had extensively discussed the experiment about the piece of a card put on the top of a can (refer to the second extract from bottom) shows how relevant it was for them to use locally available material based on their real-life situations. They appeared to be more motivated to discuss and share ideas if the events under investigation are about facts they experience in their own life and environment, which is in line with the recommended constructivist approach. An analysis of these extracts, however, shows a lack of students’ ideas about how they perceived the transition from their predictions to the reconciliation of the ideas, i.e., it was not clear on which basis they have made the predictions.

In general, however, the experiments seemed to have created or increased the student motivation to study Physics. The following statements from some students from school 2 are illustrative of this fact:



- “*I think we should have this kind of experiments more frequently because they help us to grasp the subject matter and boosts our interest in studying Physics*”.
- “*Why don’t you give us more experiments like these? I would like to practise more, particularly on my own at home*”.

Besides the positive comments that the students have given about the POE strategy, the analysis of the students’ responses to the question of what problems they may have faced with the use of the POE strategy shows another promising aspect of the strategy, which is the high level of student involvement in the experiments. This involvement is seen to be an important factor for raising the student critical thinking. Many students said that during the three steps of the POE strategy everybody in the class had to say something about what he or she thinks of the experiment being undertaken. According to students, the fact that at the end of each of the three steps of the POE strategy (prediction, observation and reconciliation) each student was required to justify his or her answer was important because each student had to explain the rationale behind his or her own reasoning. Nobody could keep quiet. This is a crucial element in enhancing student critical thinking in the sense that it requires students to reflect about the questions posed and to think about the events occurred before formulating an answer or taking any action. Still, according to students, the POE strategy enhances the support element amongst students in the class as illustrated by the following statement of one of the student:

- ‘...it [the POE strategy] *allowed us to help each other*’.

By helping each other, students can develop a sense of collegiality which is important for raising the students’ levels of confidence in everything they can do. When students collectively agree on what and how to do to find a solution to any posed problem, they can develop a number of arguments against or in favour of each of their actions. Besides, the clarity (or lack of it) of these arguments is essential for the teacher to understand the level of students’ difficulties and be able to provide students a timely and relevant feedback about their actions.

However, as referred earlier, students’ experiences with the POE strategy were not only positive. One negative aspect mentioned was the students’ unfamiliarity with the strategy. Demonstration experiments in most of schools in Mozambican classrooms, as

already mentioned in Chapter 3, are not being carried out either due to lack of equipment or poor teacher preparation. Even in those schools where demonstration experiments are performed, they do not follow this strategy. This fact posed a challenge to most of the students during the tryouts because this was their first experience. The fact was evident in some of their answers to the question about what problems they had faced with the POE strategy. The answers were:

- *“It was a problem, particularly in the first experiment, because it is not used in our lessons”*; [Student 1]
- *“It was good although my colleagues did not approve some of my ideas”*. [Student 2]

Emerging from the answer of the student 1, it seems that student difficulties may have been linked more to the lack of familiarity with the strategy rather than its application in concrete situations but with more practice and exposure to the strategy, it can help them to do better. The answer from the student 2 shows that although the students are positive about the strategy, they still need to understand that what matters most is the strategy leading to the knowledge construction rather than the learning trajectory being followed. They need to understand that their ideas do not necessarily need to be the same. Rather, the most important step of the strategy is the reconciliation of the students’ ideas where consensus is built around the intended learning outcomes prescribed for the experiment.

b) Aspects of the demonstration experiments students did not like

Some students from both schools listed a number of aspects, which they did not like. Fourteen out of 62 students (from both schools) indicated that they did not like the fact that, in the experiment nr. 1, they were not asked to represent graphically all the forces acting on the ball during its flight, namely the force of the ‘kick’, the force of air resistance and the force of gravity. They thought that a visual representation could have improved their understanding of the nature of these forces and their impact on the movement of the ball.

Few students from school 2 (six out of 41) indicated that they did not like doing the experiments in groups. They argued that they would prefer to do the experiments

individually because the sharing of ideas or answers, particularly during the reconciliation phase of the POE strategy, made the drawing of conclusions very confusing and time consuming; besides it was also difficult to describe the observed events of the experiments in groups of more than three students.

Students' experiences in connection with differences between demonstration experiments on PAM materials and regular Physics laboratory lessons

Students from school 2 indicated that they had never been involved in Physics demonstration experiments before. Specifically they stated that their normal classes were theoretically orientated with the teacher explaining how things would happen in an experimental situation. When informally asked by the researcher whether they had ever done some practical work before, they indicated that this was done through exercises normally given as homework. One student said:

“At the end of each unit we are often given some reviewing exercises to do at home. Some of these are corrected by the teacher in the next lesson”.

The students stated that they were very fascinated at being involved in demonstration experiments of this nature because the worksheets were very well structured, practical and easy to follow during the course of the laboratory class.

Many students from school 1 (16 out of 21) indicated that the difference between the demonstration experiments based on PAM materials and their regular Physics laboratory lessons was that the lessons in the tryout, were closely facilitated by the teacher and were accompanied by worksheets with detailed instructions on how to do things. During the tryout, the teacher was more involved with explaining what to do and how to carry out the activity. In this regard, one student said:

“In our regular laboratory lessons the teacher would simply tell us what needs to be done and wait to see whether or not we managed to reach the desired outcome. Today's lessons were scientific, modern, and more interactive; nobody could keep his/her mouth shut.”

Moreover students indicated that in the laboratory demonstration lessons on PAM materials they liked to discuss, interact, and construct their own knowledge, and they were encouraged to reflect on the experiments. They would first think about the

situation (during the prediction phase of the strategy), observe the course of the phenomenon (during the experiment), and compare their reflections with what actually happened (on reconciliation). This was very helpful for them in identifying and explaining the differences or similarities between their thoughts and the actual outcome. Students described the POE strategy as accurate and explanatory but they acknowledged the fact that it is somewhat time consuming. Students in general felt that the major difference between their regular Physics laboratory lessons and the tryout experiments was the guidance of the teacher and the time given to them to think about the phenomena and carry out the experiment before they were asked to draw conclusions from the experiments. It is worth mentioning that two students, who arrived late in the class, indicated that they found the worksheets difficult to follow even though they were immediately asked to join in the working groups. Apparently they had difficulties in joining in with the group particularly as they had no foundational knowledge on which to build their understanding. Three students did not respond to this question.

On the question on how they describe their participation in the experiments, the majority of the students (53 out of 62) indicated their participation as *active* and *interested*, because “*I was always contributing my own ideas*” and “*Because each of us had to justify his/her answers*”. The remaining nine students did not respond to this item. There were missing data in this item because it seems that some of the students are not familiar with the type of the question characterised by circling one or more options. Similarly, when asked what problems they might have faced during the execution of the experiments, they referred to the fact of that they had never previously participated in these laboratory lessons. As a result, students explained that: “*Some of the experiments were not easy to make a prediction* (experiment number not specified)” and “*The experiment about comparing the accelerations was difficult to understand*”.

Finally, when the students were asked for final comments or suggestions for improvement in the way the lessons were conducted, they indicated, among other things: the need for more time for them to be able to reflect about each item in the worksheet without rushing to another item; the inclusion of more topics in the experiment; the need for more frequent demonstration experiments of this nature; and

the need for experiments to be carried out individually to allow adequate visualisation. Apparently, the number of students per group had negatively influenced the participation of all students as some students actually had difficulty in seeing what was going on in the experiments. This is, however, a point of concern given the large class sizes of the majority of Mozambican classrooms.

Researcher's observations on the classroom tryout

The researcher's observations are presented in two parts corresponding to two observation phases. The first phase comprised aspects of teacher preparation for the classroom tryout in which the focus was on those aspects where teachers seemed to experience difficulties during preparation of the experiments. The second phase consisted of the aspects of both students and teacher difficulties during the execution of the experiments. More specifically, during this second phase, the researcher kept notes on how the teacher introduced the POE strategy and how s/he monitored the students' activities. Therefore, the researcher's observations are summarised under the headings of lesson preparation and execution of experiments.

(a) Lesson preparation

A week before the demonstration experiments, the teachers at both schools were provided with copies of the PAM materials for preliminary reading. They used the materials to prepare the experiments with some success and managed to try out most of the experiments in advance without too many difficulties. It seems that the teachers' reaction to the materials was positive. There were, however, some problematic aspects that were raised by the teacher from school 1 (the first school to conduct the tryout) during the meeting held a day before the experiments, which needed to be addressed in the next version of the prototype.

- There were concerns about the length of the PAM materials. The teacher felt there was too much to read and suggested that a shortened version, for instance, of the description of the assessment components (Part 2, Teacher's Guide) would be adequate. The teacher also indicated that the subsection on "Start of the lesson" (Part 3, Demonstration Experiments), consisting of brief questions for students to determine what they already knew about force and inertia

related concepts, might steal quality time from the experiments and could therefore be excluded from the Guide.

- In Experiment Nr. 2 (*Newton's Second Law*), the aspects such as (i) the reduction of the values of force (the value of the force was 6N) and of masses ($m_1=1\text{Kg}$ and $m_2=2\text{Kg}$), and (ii) the need to consider an average speed (rather than speed) when determining the value of speed of the masses m_1 and m_2 , were raised. All these problematic aspects were discussed between the teacher 1 and the researcher and the necessary amendments were made before carrying out experiments in school 2. The values of both forces and masses were found to be too high to be manageable in a demonstration experiment. As a result, the values of force were reduced to 2N, the m_1 and m_2 masses to 100g and 200g respectively and the students had to calculate average speed.

In school 2 the experiments were carried out with relative success compared to school 1.

b) Execution of experiments

The execution of the experiments in both schools started with the teachers organising students into groups. In school 2, due to the high number of students ($n=41$), the teacher did not follow the format suggested by the PAM materials (a maximum number of four students per group). Instead, seven groups of five students each and the eighth with six, were formed. After forming the groups, the teachers in both schools introduced the students to the objectives of the experiments, explained the working methodology with emphasis on the POE strategy, and asked each group to appoint a chairperson. When all groups had been formed, the teachers distributed Worksheet 1 (about the prediction phase) and allowed five minutes for student prior reading but did not ask students to pose any questions.

As the students were conducting the experiments, teachers walked around providing guidance and support where appropriate. Some students had difficulty in using correct equations for determining the values of acceleration and average speed on the Experiment Nr 2 (*Newton's Second Law*). As this phase of the experiment was carried out in groups and with the teacher support, the difficulties were alleviated. This

experiment, however, appeared to be the most laborious and time consuming of all. Discussions about getting the experiment well set up and applying the right equations for calculations continued beyond the estimated time and teachers, sometimes, seemed to have difficulties in handling the working environment. At a certain stage the researcher intervened and assisted the students. As a result, very little time was left for drawing conclusions and rounding off the lesson, particularly in school 2.

During the experiments, the practical activities seemed to be a motivation for the students and facilitated their learning. Some students argued that experiments like these could help them become good physicists, if these were undertaken more regularly. As already indicated, some of the students said that individual work is more productive than group work because of the value of discussions. However, from the researcher's point of view, this is an issue for concern because classes are large and individual practical work could prove difficult to conduct in terms of classroom management, unless teachers are capable of arranging students into small groups or pairs and then manage and monitor the discussions. Like their students, teacher involvement and motivation was also good despite the difficulties in time management. However, in some cases, groups did manage to finish their experiments within the estimated time.

An analysis of the demonstration experiment report

At the end of the demonstration experiments, students in both schools were given a demonstration experiment report template (see Appendix B of the PAM materials). The template contained an outline which would guide the students when writing their reports. It was suggested that the report was divided into a number of titled sections, such as purpose, procedure and theoretical background, as the required length of each section was indicated. To facilitate understanding, each section title was explained in detail. Specifically, the report was meant to assess the student ability to design and conduct demonstration experiments as well as to communicate experimental results. Student success in this task was evaluated by the teachers using 0-20 point scale. In general, the report was designed not only to assess the students' awareness of what should be included in a demonstration experiment report and how it should be put together, but also to support teachers in evaluating the level of student performance in this type of assessment practice.



Initially, the report was meant to be individual but, due to the large number of students per class, which implied that students be organised into groups, it was decided between the teachers and the researcher that reports be written in groups. The groups were made up of the students who worked together during the experiments. Reports were submitted in a one-week period of time as planned.

All five groups of school 1 submitted their reports while, from school 2, reports were submitted by six out of eight existing groups, making up a total of 11 reports. As referred to earlier, classroom tryouts were conducted in a school period close to the final examinations. According to the teacher T2, this seemed to be the reason why not all groups managed to return their reports; apparently students were busy preparing themselves for the examinations.

An analysis of the reports from the students' perspective indicated that they produced descriptive rather than substantive reports, which would illustrate a deeper understanding of the content. Sections about procedural information such as *purpose* and *procedure* were more accurate and explanatory of the tasks undertaken than those which required an ability to argue how they have developed their reasoning during the prediction and explanation stages of the POE strategy (*theoretical background* and *data* sections). Although the *conclusions* section also included the student ability to describe the focus of each experiment, the identification of potential sources of error and the discussion about how such errors impacted on the results proved to be difficult for students.

From the teachers' perspective, although the report template had explicit guidelines on what to include in each section, it seemed that the teachers focused their attention more on students' manipulative skills during the experiments. Their comments on student reports were more on controlling the students' description of adequate execution of the experiments (manipulative skills) dealt with in the *procedure* section, rather than other investigative skills. Aspects about (i) concept building or concept acquisition, where students would present well-described experiments and discuss the assessed concepts, and their connections with other related concepts (*data* session), (ii) the assessment of theoretical knowledge base (*theoretical background*), and (iii) the student ability to

conduct and communicate the results of the experiments (*conclusion*), were not adequately dealt with by the teacher feedback to students. This fact, however, is not surprising because teachers, like their students, lacked investigative skills needed to write reports.

Overall, the combination of both perspectives (teacher and students’) indicates that the PAM materials should also pay attention to providing support for student ability to communicate experimental results based on an integrated instructional process, investigative and manipulative skills, and the drawing of informed conclusions. Regarding teachers, the materials should provide support aimed at enhancing their critical thinking not only on procedural aspects of the experiments, but also on those aspects that require students to argue about experimental situations on the basis of sound theoretical foundations.

Having presented and discussed the findings of the second prototype, the following subsection discusses how this prototype was formatively evaluated to include suggestions given by teachers and students.

6.3.5 Formative evaluation of the second prototype: The way forward

Suggestions from the experiences with the tryout were then used to design the third version of the prototype of the PAM materials. The findings of the various stages of the classroom tryout show that, drawing on the teachers’ experiences of the demonstration experiments and use of the PAM materials, the advice was to find a balance between the number of experiments to be conducted per lesson and the time allocated to perform the experiments.

The teachers felt that, although the POE strategy seemed to be very effective in raising students’ motivation and willingness to perform demonstration experiments, it is time consuming because it involves discussions, building of consensus amongst students, and close facilitation from teachers. This balance should not necessarily be sought by adding more time to the timetable but by utilising other practices such as distributing worksheets to students before the actual demonstration experiment starts to allow for prior reading. The teachers noted also that they needed to read the Teachers’ Guide

well in advance and prepare the experiments before the normal time schedule. This forward planning and preparation illustrates the importance of teachers' commitment, which is seen as a successful factor in obtaining good results from the use of experiments in Physics learning.

Three sections of the PAM materials were considered by the teachers as the most helpful for their teaching activities, namely the Practice-Oriented Lesson Plan (Appendix P, Part 2, subsection 4), the Glossary of Terms and the Demonstration Experiment Report Template for Students (Part 5). However, they considered subsection 1.1 of the Teachers' Guide too long and suggested that it be reduced to allow a friendly use.

Students' comments about the second PAM prototype suggest that the next step would be for students to develop graphical representations on those experiments involving forces acting on a ball. A visual representation would allow the students to improve their understanding of the nature of these forces and the impact of these forces on the movement of the ball. Some of the students expressed dissatisfaction about doing the experiments in groups because the sharing of ideas during the reconciliation phase of the POE strategy made the drawing of conclusions confusing and time consuming. Students' experiences about the differences between demonstration experiments on PAM materials and regular Physics laboratory lessons highlighted the role of the teacher during the tryout as crucial to the successful running of the experiments. More comments from students about their experiences referred to the apparent unfamiliarity with question items characterised by circling one or more options and, for some of the experiments, it was not easy to make a prediction.

In writing the demonstration experiment report, students appeared to experience difficulties with those sections that required the ability to argue a point to demonstrate their reasoning (*theoretical background section*), which would show how potential errors could impact on the experimental results and consequently lead to drawing wrongly informed conclusions (*data and conclusions sections*). Interestingly these are the same sections where teachers also revealed difficulties in providing effective formative feedback. This suggests that support is needed for both students and teachers in developing in-depth thinking and reasoning skills.

As a conclusion, students' opinions and experiences about classroom tryout reveal that students appeared to like demonstration experiments. The experiments allowed the students to verify theory for themselves, and increase their understanding and awareness that Physics is related to real-world events. In addition, demonstration experiments gave them a sense of control over their own learning. Within the research literature this corresponds to affective aims of demonstration experiments in Science teaching where the use of Science demonstration experiments in a constructivist approach can effect conceptual change (Dekkers & Thijs, 1995). Another aim of the experiments is linked to clarification of the scientific method, or enhancing problem solving skills (cognitive aim). This aim, however, does not seem to have been fully met during the experiments. Students seemed unable to describe and explain the events as accurately as possible. For instance, they were unable to provide explicit reasons for their predictions of the events and how these differed from their observations. Finally, there is the aim of development of investigative skills, such as applying research methods, formulating hypotheses and drawing conclusions from data. This aim was intended to be addressed through the preparation of demonstration experiment report. In this perspective, although the report template contained substantive information about *purpose, procedure, theoretical background* and *conclusions* from data collected, students' reports were more descriptive than explanatory of the student ability to argue and explain their reasoning during the prediction and explanation stages of the POE strategy. Without completely neglecting the first aim (affective aim), the third prototype will attempt to address the last two aims namely cognitive and investigative skills aims.

All these comments and suggestions were taken into account and informed the design of the third prototype of the PAM materials.

6.4 Design of the third prototype

The design of the third prototype was based on the comments and suggestions from the classroom tryout. The main focus of the revision was to gather information on the practicality of the PAM materials in terms of layout, structure, and content presentation so that the next version would have strong elements on *effectiveness*. In



relation to the layout and structure, the prototype had the characteristics described below.

- *Presentation:* The third version of the prototype contained outlined numbering of headings to differentiate various types of information. The main headings are 1.0 Introduction; 2.0 Objectives of the lesson; 3.0 Teaching strategy; 4.0 Assessment criteria; 5.0 Demonstration experiments; 6.0 Assessment rubrics; and 7.0 Demonstration Experiment Report template.
- *Target groups:* Initially the PAM materials included information for teachers and students without separating sections for each target group. The new version showed a clear distinction between the Teachers' Guide and student worksheets.
- *The prototype:* Apart from the distinction between the support materials for the teacher and worksheets for students, these worksheets were included in the prototype and the length of the subsection 1.1 of the Teachers' Guide was also reduced as suggested by both experts and teachers.
- *The teacher's practice-oriented plan:* The subsection on preliminary discussion about force and inertia and their related concepts was removed from the teacher's practice-oriented plan in order to make the materials user-friendly.

The content presentation was also reviewed. The third prototype highlighted the main characteristics of the POE strategy and its relevance in investigating student understanding of Physics concepts. The presentation of content was specifically reviewed in the items listed below.

- *Teaching phase:* Greater detail on how the POE strategy can serve both introductory and consolidation phases of teaching and learning concepts were added in the Teachers' Guide. This was seen as a need to assist teachers understand the shift from assessing *of* learning to assessing *for* learning.
- *Lesson plan and timing:* The lesson plan and timing of the experiments was revised to accommodate the four experiments plus the assessment related activities that were not included in the previous versions.
- *Demonstration experiments:* The wording of the experiment nr. 1 (*Introduction to the force concept*), which required the students to name '...the force (s) acting on the ball' was reformulated to specify '...the force (s) acting on the



ball *during its entire flight*' and emphasised that the experiment occurs under an idealised system where the force of air resistance is neglected. A picture showing the kicking of the ball and its trajectory was also included. The experiment nr. 2 (*Newton's Second Law*), which proved to be time consuming and in which students showed difficulties, was replaced by another demonstration experiment on comparing different forces acting on moving objects. This new demonstration experiment was intended to help students identify and compare forward and backward forces exerted on a moving object at constant speed (refer to demonstration experiment nr. 2 in Appendix P).

- *Demonstration Experiment Report template*: The content of the report template was also reviewed on the basis of the analysis of the reports received from students and the teachers' feedback to students. Improvements were made by giving additional explanations for the section of 'theoretical background' to allow students a better understanding and to assist in developing their reasoning skills. The improvements included asking students to focus explicitly on the two investigated concepts (force and inertia) and not on any other related concepts that they may have dealt with during the experiments. The new wording no longer named the related concepts to be included in the discussion with the intention to allow that students themselves be able to identify those which are worthy of discussion. It was also noted that the initial wording required excessive theoretical information (e.g., a discussion about diagrams, graphs, tables, and other visuals that the students had seen during their lessons), and this made the section lengthy and less specific. As a result, the number of pages for this section was reduced from four to three.
- *Assessment rubrics*: Students must be made aware of the levels of performance expected of them. Therefore, teachers were now given about 20 minutes to explain to students the assessment rubrics being used to assess their performance in the experiments.
- *Correction guide*: Correct responses to the experiments as well as clarifications, where deemed appropriate, were to be provided in the third version of the prototype.

Following this revision, the third prototype was produced and appraised by two experts in an interactive discussion. The results of the experts' interactive appraisal are presented in Section 6.5.

6.5 Final appraisal resulting in the fourth prototype

The appraisal of the third prototype that resulted in the fourth version was undertaken in two stages. The first stage consisted of expert appraisal and the second of an evaluation workshop with teachers. Both stages were used as a systematic reflection and documentation of the materials in terms of their expected *effectiveness* and *sustainability* of the study.

For the expert appraisal, two experts – out of the three who appraised the first prototype - were asked to focus their attention less on the practicality and more on the effectiveness of the PAM prototype including the effectiveness of the intervention as a whole. These experts were selected for their ample experience in designing curriculum materials, and in assessment and evaluation. Other areas of interest also included projects evaluations and the relationship between language (particularly English) proficiency and (mathematics) achievement. Although the experts involved in the appraisal of this version gave positive comments, indicating that they perceived the material as useful in supporting teachers in the improvement of their assessment practices, they felt that the focus of the intervention – improvement of teacher assessment practices – was not effectively addressed. They also expressed concerns about the structure of the material overall (refer to the four support levels presented in Chapter 4, subsection 4.4.3). Regarding the focus of the intervention, they suggested that this could be done by explicitly addressing the aspect of teachers' provision of feedback to students based on the assessment strategy applied.

The experts also suggested revision of the structure of the material, taking into account the four support levels (subject knowledge, lesson preparation, teaching methodology and assessment and feedback), and their advice focused on the need to present the material in the PAM prototype according to the way teachers would use it in the classroom. More specifically the experts' advice emphasised improving the specificity of the material to make sure that there is clarity on how teachers are to collect evidence

(i.e., written? per group discussions? whole class discussions?), when conducting formative assessment, and then how to use the evidence to develop a formative assessment.

For the evaluation workshop, two groups of material users were invited. Three university students who had appraised the prototypes in the early stage of the intervention, and the two teachers who had tried out the materials in the classroom, participated in the workshop. The university students are also Physics teachers teaching in high schools. All participants were asked to evaluate the materials and reflect on their *effectiveness* before implementation on a large scale. Aspects of effectiveness included, amongst others, the use of the different functions of assessment for designing classroom assessments, the use of the practice-oriented lesson plan for preparing and conducting lessons, the application of the design guidelines for monitoring demonstration experiments and providing feedback, and the evaluation of the proposed demonstration experiments in terms of the practicality of the POE strategy.

In order to capture the reflections of the participants in the workshop, Guskey's model of evaluation (2000) was employed during the workshop. According to this model, five levels of evaluation can be taken into account from the users' initial concerns about an innovation to what might happen in practice. These levels are (i) teachers' first reactions, (ii) teachers' learning, (iii) nature of school support, (iv) teachers' new knowledge and skills, and (v) student learning outcomes. Table 6.6 shows the evaluation levels of the Guskey's model with the main questions linked to each level.



Table 6.6: The five levels of the Guskey (2000) model as applied to this study

1	Teacher reactions	<ul style="list-style-type: none"> Did the Physics demonstrations experiments meet the teachers' expectations? Did they consider the content, process and context of the experiments useful and relevant?
2	Teachers' learning	<ul style="list-style-type: none"> Did teachers acquire the intended knowledge, skills and attitudes towards demonstration experiments?
3	Nature of school support	<ul style="list-style-type: none"> Did the respective schools support the implementation of the Physics demonstration experiments?
4	Teachers' new knowledge and skills	<ul style="list-style-type: none"> Did what teachers learn affect their classroom assessment practices?
5	Student learning outcomes	<ul style="list-style-type: none"> What would be the impact of the Physics demonstration experiments on the student learning outcomes?

During the evaluation workshop, the emphasis was given to Guskey's first, second, and fourth levels of evaluation, which focus on teachers' reactions to the intervention, teachers' lessons from the demonstration experiments, and the effect that the new knowledge and skills that the teachers have gained might have on their classroom practices. The reason for not considering the third (nature of school support) and fifth (student learning outcomes) levels is that these are long-term indicators, which could not be verified at the time of the study. Assessment materials need to be empirically tested with the target population and fully implemented on a large scale to be able to effectively evaluate the impact of the intervention on the student learning outcomes as well as the level of school support to the innovation.

Workshop findings about teachers' reactions (first level) and their learning about demonstration experiments (second level) indicate that the content addressed by the experiments is relevant for student learning and the context in which the demonstration experiments are carried out, is also appropriate. However, the teachers appeared to be concerned about the process of implementation of the intervention. The concerns are at students' management level: The step-by-step POE strategy requiring close monitoring by the teacher might be problematic if suitable class management strategies are not adopted. These concerns were shared by both teachers and university students. They were all of the opinion that it takes time to effect a change and as such, they will need to implement the innovation more regularly in their classrooms to be able to evaluate the impact of its outcomes. In fact, they attested that, after participating in the tryouts

and studying the exemplary PAM materials, they were willing to try out the materials in their respective classrooms.

Guskey's fourth level highlights the effect of teacher learning on changing their classroom assessment practices. The findings show that teachers have gained some additional knowledge input and experience that may improve their skills regarding the design and monitoring of appropriate assessments (particularly performance-based assessments) following the POE strategy. Although it was also difficult to get a clear picture of how teacher learning could affect their practice, it became apparent that the participants as a group had improved content wise and that there was a willingness to engage in new practices which is, in its own, a sign of success. There were, however, some concerns at a personal level. A few of the teachers seemed to be unfamiliar with some of the assessment terms or concepts used in the PAM materials. According to the participants, support from their school Boards and from the MEC via professional development workshops could help to deepen their knowledge and develop and sharpen their skills. Without this kind of support, a shift from the actual teaching and learning routine might prove to be difficult due also to its implications on schools' timetables. Once more, to realise the effective improvement of the actual assessment practice requires time.

All these questions, suggestions and comments were taken into account in designing the fourth and final prototype of the PAM materials (Appendix P). The final prototype consisted of five parts namely Part 1 (Introduction for the teacher), Part 2 (Components and functions of assessment), Part 3 (Design guidelines and feedback provision), Part 4 (Demonstration experiments), and Part 5 (Student worksheets). As a result of the suggestions from the classroom tryout, appraisal, and evaluation workshop, substantive changes were made to Part 2 (Components and functions of assessment) and Part 4 (Demonstration experiments). The glossary of terms used in the prototype that constituted a section in its own in the first prototype, was embedded in Part 5, and a new Part 3 (Design guidelines and feedback provision) was added to explicitly address the issue of designing, monitoring and assessing demonstration experiments, as well as providing feedback to students. In summary, relevant changes resulting in the fourth prototype included the contents of Parts 2 and 4 as well as the creation of a new Part 3. These changes are discussed below.

Part 2: Components and functions of assessment

The core of this research is to improve teacher assessment practices. To achieve this purpose, explicit attention was given to support of teachers in designing and applying appropriate assessment strategies for student learning. This section provided firstly an explanation of *components and functions of assessment* to help teachers develop their own assessments. Secondly, a practice-oriented Teachers' Guide containing the *sequence of content and lesson plan, some logistical aspects*, and a *plan* on how to teach and assess following the POE strategy, was given. The Teachers' Guide (practice-oriented lesson plan) was structured in such a way that it follows the four support levels discussed in Chapter 4 (refer to subsection 4.3.2.3) with emphasis on assessment and feedback for the teacher on how to conduct the experiments, what to assess, and what type of feedback should be given to students.

Part 3: Design guidelines and feedback provision

This section provides guidelines on how to design and monitor demonstration experiments in the classroom and to facilitate student learning through provision of formative feedback. Five design elements, as taken from literature, (refer to Chapter 4, subsection 4.3.2.3) are discussed in this section and they are listed below.

a) Agreement - *the teacher and the students must agree on the relevance of the problem to be investigated, the procedures to be followed, and the conclusions of the evaluation of the explanations given during the experimental work. This means that the students must understand the relevance of the problem being investigated. As Dekkers (1997) and Tamir (1991) indicate, (i) the teacher's intended purpose should become the students' own purpose, (ii) the activity designed to achieve this purpose is to be understood and accepted by the students, and (iii) the students' conclusions are to be discussed, valued and related to the teacher's hoped-for conclusion. By getting involved in all these stages, students would then understand the intended purpose of the practical work and perceive the task as relevant.*

b) Intended learning outcomes – *the teacher must be prescriptive about the ideas that the students are supposed to acquire and develop (Dekkers, 1997). The students must understand the procedures to be followed in order to achieve the proposed ideas.*

This is important as a criterion to verify the effectiveness of the experimental work. It is, therefore, crucial to be aware that these ideas may not be acquired at the end of the task. If this happens, however, it means that the teaching process or the design and implementation of the experiment may have not been successful and a revision of these aspects is needed.

c) Student participation – *In experimental work, particularly in demonstration experiments, the teacher must produce the event to be investigated according to the purpose to be achieved, while the students attempt to interpret it and make sense of it.* In so doing, the teacher may find a balance between his/her expository approach (which has its own educational value) and the student-centred exploratory approach. An intended conceptual development can equally take place when having each student handling the equipment her or himself or when some students observe others handling the equipment but acquiring information about the event under investigation (Garrett & Roberts, 1982). One of the most important aspects in students' participation in the experiments is that they should be able to relate the proposed task to previous activities, and the understanding of the relationship between the proposed procedure and the purpose to be achieved is crucial, even if they do not handle the equipment directly.

d) Type of experiments and aims - *Teachers must avoid having too many experiment aims to be achieved at once. This may lead to none being pursued (Hodson, 1993). Rather, they must select the proper experiment for the chosen aim and match the written instructions.* Students should not be involved in activities that may distract their attention from the aim of the experiment. Several authors point out that side-issues such as getting the equipment to work, data acquisition, extensive data manipulation, and complex measuring procedures are all 'noise' that can lead the students to perceive each of them as the main purpose of the practical (Gunstone, 1991; Johnstone & Wham, 1982; van den Berg & Giddings, 1992). It is suggested that experimental work must rather concentrate on qualitative observations (e.g., in concept acquisition) and finding a balance between a too complex and a very trivial task.

e) Critical thinking and reporting – *Teachers are to make sure that students develop a critical attitude towards their actions and interpret the activity data only in the light*

of the experimental work pursued and of their own knowledge and experience. Students should also be able to summarize and report the main aspects of the experiment including the central aim and outcome, the basic methods applied, and the underlying theory of the demonstration experiments.

In relation to feedback provision, a list of aspects aimed at supporting teachers on how to provide formative feedback to students, particularly during the course of the experiments, is provided (see also Chapter 4, subsection 4.3.2.3). The list contains procedural information on how to support teachers from lesson preparation to lesson evaluation (summative assessment). The reason for selecting these aspects is the recommendation by the literature as being effective for monitoring the student learning during performance assessments and were successfully used by a similar study about practical work (refer to study by Motswiri, 2004). It is, however, important to note that this list does not intend to suggest reinforcement of rather traditional (i.e., teacher-centred) curriculum implementation of Mozambican teachers but it deliberately contains statements on what is perceived to be relevant teacher actions for the context of demonstration experiments. These elements of feedback provision indicate that when facilitating demonstration experiments, teachers must be able to:

a) Lesson preparation

- Take time to read the support materials and reflect on the experiments well in advance. It helps clarify ideas about the outcomes being pursued.
- Assemble and try out each experiment before the actually lesson starts. It is crucial for detecting potential problems (e.g., shortage of equipment, time constraints for conducting the experiment, inappropriate set-ups and procedures).

b) Course of the lesson

- Start the lesson by asking brief introductory questions to students on what they already know about concepts or events to be investigated.
- State the objectives of the lesson, clarify the outcome to be achieved at the end of the experiment(s), and explain the teaching and assessment methodology to be followed (including the procedures).

- Observe what students do and ask probing questions to help them reflect on their activities. This is important to focus students' attention on important elements of the experiment.
- Encourage students to discuss amongst each other. It helps to develop their own models of learning and the capacity of the class to function as a community of learners.
- Give opportunity to students to reflect on their own tasks and on those of their colleagues in a critical way.
- Keep in mind that the teachers' role in the experiments is to help students develop their reasoning, and act mainly as a moderator.

c) End of lesson

- Provide immediate feedback to students (when asking probing questions) so that they understand to what extent they are achieving the intended purposes. The feedback should preferably be individual and either congratulatory or critical.
- Round off the lesson by providing a summary of the main conclusions of the demonstration experiment. Give students homework and ask them to prepare a short report about the experiment(s). Due to large classes and time constraints, a follow-up to the homework and experiment reports can be given during following lessons.

Part 4: Demonstration experiments

The fourth prototype was comprised of four demonstration experiments following the POE strategy. Substantive changes refer to the fact that in this section each of the experiments had applied the design guidelines and the specific elements of feedback provision presented and discussed in Section 3 of the PAM materials. All aspects of lesson objectives, intended learning outcomes, activities during the experiments, assessment and feedback (on monitoring and provision of feedback), and summative evaluation of the experiments (using assessment rubrics) were taken into consideration in this version. At the end of the section, a glossary of terms used in this prototype and a report template to guide students in preparing a report to summarise the experiments are given. The final version of the fourth prototype is presented in Appendix P.

Section 6.6 summarises the conclusions drawn from both the classroom tryout and the evaluation workshop, and discusses the design principles, which were used to address, in the PAM materials (refer to Appendix P, Part 3), the issue of designing and monitoring demonstration experiments, as well as the teachers' provision of formative feedback to students.

6.6 Conclusions and implications for further development

The central research question of this study, which is addressed by the intervention study, investigates how teacher assessment practices could be improved. Based on preliminary information obtained from the Baseline Survey and on what emerged from the literature as good practice, a choice was made to design and try out assessment materials on performance type of assessment in the context of demonstration experiments. It was assumed that, by supporting teachers in designing and trying out assessment prototypes in one type of assessment practice and in a given context, the teachers would be able to transfer their knowledge and skills to other assessment practices. A number of prototypes were designed and subsequently evaluated to examine the quality of the lesson and assessment materials in terms of validity, expected practicality and expected effectiveness. While the concepts of validity and practicality were given more emphasis during the prototyping phase of the intervention, expected effectiveness was more emphasised during the systematic reflection and documentation which were carried out through the evaluation workshop and final expert appraisal.

Teachers' general impression about the PAM prototypes and their opinions about the experiments show that they perceived the materials to have the potential to improve their assessment practices in the context of demonstration experiments in their classes, because the suggested POE strategy allows students to be actively involved in meaningful individual and group tasks. On the practicality of the materials, teachers were seen to have problems in terms of its length – particularly the Teachers' Guide. Teachers were also observed to find problems in developing a meaningful formative assessment orientation during the experiments and drawing lesson conclusions. This fact was due to the reported lack of explicit advice on feedback provision from one

side and on the lack of sufficient time to conduct the experiments and guide final discussions leading to final conclusions. Teachers also perceived the exemplary materials as being inconsistent with their ordinary classroom practice, because they involve additional time and costs, which teachers perceive as hindering the successful implementation if not taken into account by all educational stakeholders, namely students, teachers, school leadership, Parents' Councils and the MEC.

Students' comments on PAM prototypes and on the experiments showed that, although they are unfamiliar with the POE strategy, they enjoyed the materials and the activities and would like more practice and exposure to the strategy. They perceived the worksheets as being easy to follow and the strategy as wonderful in terms of the potential to raise their chances of being engaged in addressing the problems and generating solutions by voicing their own ideas. Students appreciated the role of the teachers as facilitators during classroom tryouts and their own roles as active students.

Experts have also indicated that the PAM materials have great potential in improving the teacher assessments. However, they emphasised that explicit attention needs to be paid in providing guidelines to teachers on how to apply assessment practices for learning and on provision of effective formative feedback to students.

Drawing from the reflections of the final experts' appraisal, the evaluation workshop findings, and in combination with relevant literature reviewed on this respect (Chevane, 2002; Dekkers, 1997), a number of design principles for successful student assessment, in the context of demonstration experiments, are to be taken into consideration. These principles are listed below.

- Clarity - students should understand the intended purpose of the experiment.
- Relevance - students must perceive the laboratory experiment as valuable to assist in learning.
- Understanding - students must understand the procedure to be followed during the experiments and be able to execute it.
- Relationship - relating the proposed task to previous activities and understanding the relationship between the proposed procedure and the purpose to be achieved is crucial.

- Critical thinking - students must be challenged to use their knowledge and experience to develop their critical thinking which would assist them in the conducting of the experiments, the interpretation of evidence and the drawing of conclusions.
- Reporting - students should be able to summarise the main aspects of the experiment including the central aim and outcome, the basic methods applied, and the underlying theory of the experiment.

Many examples in the literature report positive experiences in students learning but they are not necessarily suitable for enhancing the assessment process. For instance, Tamir (1991) refers to some principles which bring about positive effects for instruction in general, and are based on a learning-cycle approach. This approach stimulates students to formulate questions and the teacher to introduce and explain new concepts, as well as apply results in new situations. The principles listed above were selected for being suitable for the Predict-Observe-Explain approach suggested by this study. They intend to support teachers in designing and applying meaningful assessments. ‘How-to-do’ advice on monitoring the process of assessment and providing feedback was given in Section 6.5. For instance, on the issue of reporting, students found it difficult to summarise meaningfully the important aspects of a small demonstration experiment they had just undertaken but rather recall some of their manipulations in the laboratory. In this case, the teacher should be able to provide students with the opportunity to reflect on their own tasks, develop critical thinking (e.g., by asking pertinent questions), and then understand to what extent the students have achieved the intended purpose. This can be achieved by following the design guidelines and elements of feedback provision discussed in Section 6.5.

It was against the findings from the classroom tryout, the suggestions from experts, as well as in connection with what the literature says are good practices for classroom assessment that the current version of the PAM materials was designed. Although the potential of the materials is acknowledged, it is important to note that the fourth version of the PAM materials cannot be seen as final because, as started in earlier chapters (see, for instance, Chapter 4, subsections 4.3.2.1 and 4.3.2.2), the study has only capitalised on the potential of the material for improving assessment practices for teachers. This potential was sought through investigation on expected practicality and

expected effectiveness. The materials can only be accepted as finished products when its final version has been tried out repeatedly with a number of users in schools. It is also noteworthy to state that there are still areas of improvement both in terms of the quality of the material itself – the process of teachers’ feedback provision – and of the implementation of innovation within the current classroom context which is characterised by overcrowded classrooms, syllabus time constraints and limited school budgets. For instance, the issue of overcrowded classrooms is a reality for the majority of African schools. In the Mozambican context, if this is not adequately addressed, it could make the proposed POE strategy in the context of demonstration experiments a difficult approach to implement. Literature (Chevane, 2002; Cossa, 2007; Dekkers, 1997; Hodson, 1993) shows that the strategy can be successful if students are working in small groups. These authors argue that there are several factors to consider when designing and implementing the strategy particularly in the context of experimental work. These factors, which serve as guidelines for the design of successful experimental work, are summarised below.

- *Closed or open-ended*

A question about practical work (e.g., demonstration experiments) that is very often discussed in the literature is whether formulating the problem, designing an execution strategy, and drawing the conclusions should or should not be left to students alone (Dekkers, 1997; Hodson, 1993; Tamir, 1991). Tamir (1991) presents the degree of openness on students’ inquiry skills at four levels (Levels 0 to 3). At Level 0, problem, strategy (or procedure), and conclusion are all given to students and they only need to collect data and check whether these data are ‘correct’, while at Level 3 all activities are carried out by the students. The literature, however, argues that what matters is not whether all inquiry skills are predetermined or not, but whether the teacher and the students agree on the relevance of the problem, the adequacy of the strategy, and the conclusion of the evaluation of explanations given.

- *Prescription of the learning outcomes*

An evaluation of the effectiveness of the demonstration experiments is a very crucial step. Before guidance and support are provided to allow teachers and students to reach the intended outcomes, it is necessary to prescribe the ideas that need to be acquired and understood. If, however, the prescribed ideas are not met, this would mean that

some decisions were not well taken care of (e.g., the procedure followed was inadequate, the designer’s arguments for reaching the ideas were different from those of the students), and the teaching and assessment strategy will need to be reviewed.

- *Course of the demonstration*

A decision is needed on whether the students should handle the equipment or material themselves or whether the intended outcome can be reached by only having them observing other students (or the teacher) doing the experiments. This decision, however, should consider that demonstrations may have the value of student-centredness where the teacher (or other students) may produce the event, while the students interpret and make sense of it. But an important factor, as illustrated by some student statements during laboratory demonstration, is that having each student handling the equipment is better and gives them the opportunity to ‘play’.

- *Relationship between the type and complexity of the experiment and the aims*

Too many experimental aims to be met at once can lead to none of them being attained (Hodson, 1993). It is important to avoid issues that can distract students from the actual purpose of the experiment. As Johnstone and Wham (1982) point it, this is ‘noise’ that can produce counter-productive effects. For instance, if the teacher does not clearly define the problem to be investigated, does not indicate the procedure to be followed, or does not get the apparatus to work in time, each of these could act as the main purpose of the experiments for students. Furthermore, besides clarity in defining the aim, it is also important to select adequate experiments for the chosen aim and match the written instructions with these (van den Berg & Giddings, 1992).

Some ‘open ends’

As experts have indicated, the PAM materials need to have clearly formulated design principles for their successful use by teachers and students in the context of demonstration experiments. It was argued by teachers and supported by experts that the POE strategy is an approach that can optimise student learning if it is accompanied by continuous provision of feedback. This argument is valid when taking into account that more emphasis was put on the lesson materials in the early stages of the intervention and only later, on assessment strategies and feedback provision. This reinforces the idea that the POE strategy combines instruction with assessment.



The teachers who participated in the classroom tryouts and in the evaluation of the intervention, also perceived the materials to have the potential to improve their assessment practices. Whether its successful implementation would actually take place depends on the involvement of all other educational stakeholders (e.g., the school leaderships and the MEC) particularly in the way they might address the involved costs and additional time required. Relevant literature on experimental work has provided promising design guidelines that can support teachers and students in successfully implementing the changes but it has been argued that the guidelines are mostly effective when working in small groups of students. The fact is that with or without overcrowded classrooms, a successful implementation of the innovation, within the current Mozambican classroom context characterised by syllabus time constraints and limited school budgets will need time to be achieved. But one thing is certain: a lack of support for teachers in designing and implementing alternative assessment strategies that contain procedural specifications on how to provide effective feedback to students can be detrimental for the future of student learning.

The final version of the PAM materials designed in this study contains specific design principles for designing and implementing successful demonstration experiments. Further evaluation research on the impact of the implementation of the suggested assessment practices and innovations is required, given the fact that, although the classroom tryouts were adequately developed and conducted, time constraints did not permit an opportunity to try out the fourth version, evaluate it, and draw definite conclusions about the long-term impact of the intervention.