results show a direct significance of productive practice in school Mathematics to promote mathematical concepts and procedures. The next section deals with reflection on the implementation of designed activities.

5.3 Reflection on implementation

After implementing the designed activity 1, I noticed that some participants did not master integer arithmetic. On the following day of implementation, I then decided to give them a test to write for 10 minutes. A class test is not in line with design-based research and a class test was probably not an appropriate way to deal with the problematic issue after I implemented designed activity 1.

What I did not do correctly in line with design-based research is when I asked the participants to write a test after I implemented designed activity 1. When I asked the participants to write test was not in line with design-based research because design-based research tries to pinpoint the issue that participants struggled with and then adapt the designed activity to ascertain if participants dealt with the designed activity in a better manner. Design-based research is about the knowledge gained through the experience of the work of the researcher combined with the knowledge gained from research.

Based on other groups` written responses, the implementation of question 3.1 was not better than questions 1.1 and 1.3. The following day I decided to give participants feedback on question 3.1 and I think that was important for the learning goal. In terms of design-based research, feedback assists in intervening to address the complex educational problem.

In designed activity 2, some participants did not finish their written responses within 10 minutes, so I gave participants three minutes extra time for them to conclude their written

responses. Three minutes of added time was a correct decision in line with design-based research because my end goal was to provide a qualitative explanation of what was happening inside the classroom.

Before I implemented designed activity 3, I asked participants to form new groups. I think that was a correct decision in terms of design-based research. When I asked participants to form new groups, I intended to encourage sharing of ideas among themselves. Furthermore, I saw the necessity to go beyond narrow procedures of learning and address the nature of learning in context.

When some participants kindly asked me to explain and do one example for them, I asked participants to read the instructions carefully and read them two times when necessary. I refused to give them answers for any designed activity and I reminded participants there was nothing wrong when their written responses were incorrect. Refusing to provide participants with answers was correct in terms of design-based research. My main objective was to increase the translation of educational research into improved practice, and improved practice is in line with design-based research.

I think I revealed the effectiveness of designed activities and productive practice through the application of design-based research. When I implemented the designed activities I think I improved measures of learning to understand the "how" question and not to explain. During implementation, I did not try to prove to the participants that productive practice is better than any other teaching strategy and I think that was in line with design-based research.

When I implemented designed activities a productive practice perspective improved the delivery of mathematical content to realise a specific goal. For instance, on the following day of implementation for each designed activity I ensured that participants presented their written

responses on the whiteboard to enhance mastery of integer arithmetic. The efficiency of designed activities ensured participants were demonstrating competence with integer arithmetic. My designed activities linked up with the general objective of design-based research.

The duration of the designed activities was adequate because it took 10 minutes for some participants to finish each designed activity. This means that for the effective implementation of productive practice to take place, one person has to reserve 10 minutes of the lesson. The implementation of productive practice might not work well in less than 10 minutes.

The designed activities were clear and understandable to all participants. The resources used in this research study were of high excellence. I made the participants conscious of what and where they should be at the end of each designed activity. This study enhanced my approach to the teaching of Mathematics.

In designed activity 1 the designated time was too short for some participants to finish the designed activity 1. I honestly think the designed activity 1 was too long to be done in 10 minutes. For instance, in designed activity 1 the participants had to do five questions without using a calculator.

What might have contributed to participants exceeding my designated time is the fact that the designed activity 1 had 5 questions. In designed activity 1 the participants would take a shorter time if the designed activity 1 was reduced to three questions instead of five questions if the activity becomes used in the classroom procedure.

In designed activities 2, 3 and 4, the designated time was not too short and designed activities 2, 3 and 4 were not too long to be done for 10 minutes. From my perspective, what contributed to some participants exceeding my designated time is the novelty of designed activity

2. The participants had to make an understanding of the mathematical statement first before answering designed activity 2.

What might have contributed to some participants exceeding my designated time in designed activity 3, is the fact that I did not consistently do similar questions to designed activity 3 in classroom procedure. In designed activity 4 some participants did all the questions in less than 10 minutes and some participants did all the questions within 10 minutes. As a result, my designated time in designed activity 4 was neither too short nor too long. The participants would use the shorter time when doing activities similar to designed activities 2 and 3 more often in classroom procedure.

From my perspective, the designated time was too short for some participants to complete designed activity 5. However, the designed activity 5 was not too long. Participants might have exceeded the designated time because of the novelty of the activity. The participants had to carefully replace the symbols with the correct operational signs so that the mathematical statement was true and I think the mathematical statements also contributed to participants exceeding the designated time.

Some participants seemed unsure whether they had to use the operational sign once when answering designed activity 5. I think the participants will use shorter time in the classroom procedure when doing similar questions to the designed activity 5. As a researcher, I noticed that for some participants to have done all five designed activities without using a calculator under my undivided observation came as a surprise and that might also have contributed to some participants exceeding my designated time.

Designed activities helped me to stay focused on the intended outcomes. As the researcher, I learned that it is significant to request the participants to read the instructions carefully before they proceed with designed activities. When the instructions are read with understanding by the participants, then the intended outcomes are reached. The next section deals with some recommendations for further research.

5.4 Recommendations for further research

For further research, I recommend that participants should not be asked to write a test after implementing the designed activity because a test is not in line with design-based research. A test is not an appropriate way to deal with the problematic issue that participants are struggling with and hence I do not recommend a class test to be used in research when participants struggled with designed activity. Participants should be given feedback the following day of implementation for the learning goal and to enhance participants` academic performance.

When some participants do not finish the designed activity within the designated time, I recommend participants be given three minutes to complete the designed activity and write their conclusion to ascertain the purpose of the research and provide a qualitative description of what was happening inside the classroom. I recommend participants form new groups before implementing the next designed activity. When participants form new groups, the participants will be able to share ideas amongst themselves. I recommend a researcher go beyond narrow measures of learning and address the nature of learning in context.

When some participants ask for assistance from a researcher, I recommend that participants should be requested to read the instructions carefully and always be reminded that there is nothing wrong when their written responses are incorrect. When participants are given a chance to do

designed activities, a researcher increases the translation of educational research into improved practice. During implementation I recommend that a researcher should always be careful not to try to prove to participants that a certain teaching strategy is better than any other teaching strategy.

For further research I recommend that additional learning resources should always be made available during implementation to enhance the delivery of mathematical content and to realise a specific aim. I recommend that all designed activities should be clear and comprehensible to all participants. Before implementation a researcher should be considerate not to have more questions in each designed activity.

Questions asked in each designed activity should always be in line with the designated time. When some participants finish the designed activity before time, I recommend that they should be given another activity to do so that they do not interrupt other participants. I recommend a researcher be considerate of the novelty of designed activities so that participants do not exceed the designated time. When a designed activity needs to be done in not more than ten minutes, I recommend a researcher give participants at least three questions.

A researcher should ensure that the instructions are read with understanding by the participants so that the intended outcomes are reached. I recommend the implementation of designed activities when teaching integer arithmetic as it provided the desired results in my study.

I recommend the idea of planning and preparation before the lessons start and I recommend the notion of adhering to such principles. Furthermore, I recommend thorough planning and preparation should lead to the advanced use of more quality resources in classroom activities. The enhanced resources might lead to enhanced participants` procedural understanding of mathematical concepts.

More spaces should be added to the designed activities for the participants` written responses. The participants should be made conscious of what and where they should be by the end of each designed activity. I recommend that research be done in ways to facilitate discussions of mathematical ideas among participants.

I recommend integer arithmetic to be taught in small steps and be allocated extra time in a grade 9 Mathematics class. For instance, if participants have to complete integer arithmetic within three weeks then it should be extended to 4 weeks. When it comes to the introduction of integer arithmetic in a grade 9 Mathematics class, I would recommend designed activities to master integer arithmetic. Such assistance in the designed activities would help participants to answer what is required.

I recommend a further study that would expand the target group into at least two classes instead of one classroom. Another study could look at what would happen when one classroom is daily making use of productive practice without any assistance from the researcher and the other one has been given an opportunity when the researcher reads the questions for the participants to provide more understanding and clarity on what is being asked. My study was allied to productive practice, therefore, I recommend a comparative study between the two different classes.

I recommend an experimental study between two classes to enhance participants` mastery of integer arithmetic. This would involve choosing two different classes whereby one class will be randomly allocated to make use of productive practice and the other one without productive practice. An experimental study would be done to check which classroom attained a better understanding of mathematical concepts and procedures involving integer arithmetic.

The objective of my recommendation in the previous paragraph seeks to know which class would best produce more mastery of integer arithmetic when taught through the implementation of productive practice.

Furthermore, I recommend research that will encourage participants to discuss questions that include perspectives and different discussions when it comes to mathematical concepts and procedures. Sometimes it is even better to use more open questions to ascertain participants` discussions where there are great possible answers and perhaps more than just one correct one to increase the learning ability through group discussions. The next section deals with the conclusion of the study.

5.5 Conclusion

In Chapter 5 I discussed the research results reported in Chapter 4 and reflected on the design of five activities dealing with integer arithmetic in a grade 9 Mathematics content from the design research perspective. Recommendations for further research were discussed based on reflection on implementation. I will include the uses of non-programmable calculators for integer arithmetic from a productive practice perspective in further research. When participants do computations in a grade 9 Mathematics content they should be allowed to use a non-programmable scientific calculator since it is stated in the pilot General Education and Training (GET) examinations. It was remarkable to see some participants master integer arithmetic in a grade 9 Mathematics class when designed activities were implemented and how productive practice perspective was implemented as part of "normal" teaching.

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APPENDICES

APPENDIX A

THE DESIGNED ACTIVITIES ON INTEGER ARITHMETIC

Activities 1 – 5

ACTIVITY 1: (Spiral Revision)

1. Simplify the following **without the use of a calculator:**

1.1 $5 - (-3 + 2) - 11$

1.2 $-5 - (-12) + 7$

1.3 $-12 \div 4 - 3(2)$

1.4 $-22 \div 11 - 5 - (-3)$

1.5 $\frac{5-(-5)}{2-(-6)}$

ACTIVITY 2 (Deepening Mathematical Thinking)

2. Mathematical statements can be sometimes true, always true or never true. Mark with a cross (X) the correct block for the given mathematical statement.

Mathematical statement	**Always True**	**Sometimes True**	**Never True**
When two integers are multiplied, the product is larger than any of the two integers.			

2.1 Give reasons with possible examples for your choice:

ACTIVITY 3: (Deepening Mathematical Thinking)

3. Answer the following questions:

3.1 A learner is asked to subtract $3 - x^2 - 5x$ from $2x^2 - 12 + 5x$. Here is her solution:

$2x^2 - 12 + 5x - 3 - x^2 - 5x$

$= 2x^2 - x^2 + 5x - 5x - 12 - 3$

$= x^2 - 15$

Explain why you agree or not with the way she did it?

3.2 The multiplication and division questions below have been marked by the teacher. Explain why each answer that has been marked as incorrect is indeed incorrect. Write the correct answer.

3.2.1 $4 \times -5 = 20$ **X**

3.2.2 $-40 + -5 = -8$ **X**

3.2.3 $30 \div -5 = -6$ √

3.2.4 $-14 \times -2 = -28$ **X**

Activity 4 (Deepening Mathematical Thinking)

4. Check whether the answers in pair are equal. Explain why they are the same or different.

4.1 $5 - 22$ and $22 - 5$

4.2 $-17 - (+12)$ and $+12 - (-17)$

4.3 $-8-(-19)$ and $-19-(-8)$

Activity 5 (Spiral Revision)

5. In the mathematical statements below the symbols #, *, Δ and □ stand for one of the operational signs +, -, × and ÷. Replace the symbol with the correct operational sign so that the mathematical statement is true.

5.1 1 * (-2) # 2 = 5

* = ……; # = ……

5.2 1 Δ (-2) □ (-2) * 2 = -1

Δ = ……; □ = ……; * = ……

5.3 1 # (-2) Δ (-1) * 2 = 1

= ……; Δ = ……; * = ……

APPENDIX B
Parent/Caregiver consent letter

Research title: Implementing productive practice in a grade 9 Mathematics class: A design research study.

Name and Degree	Phone Number	E-mail
Mr. Luxolo Mlofane, M.Ed. in Mathematics	063 353 8246	3375617@myuwc.ac.za

Dear Parent/Caregiver

I am investigating a way of teaching to find out whether it will assist with the improvement of your child`s results in examinations in Mathematics. Your child will not be taught topics that are different from what I must teach. The only change I will make is to, during my normal lessons, ask learner to do specially designed mathematical exercises on work that has already been completed.

I will, from time to time, write notes on, audio- and video record how your child is working with normal (as in their textbooks) and the specially designed mathematical exercises on work that he or she have already completed. This is to assist with the improvement of the mathematical activities so that your child will be able to deal with similar or related problems in examinations.

I will also require your child to periodically complete a questionnaire on his/her experiencing of the teaching of Mathematics. The questionnaire will be completed under my supervision. The learner has the right not to participate and may at any time withdraw from completing the questionnaire. Under no circumstances will the name be revealed and she/he will not be asked to write her/his name on the questionnaire. Furthermore, I will display no image to identify of your child when I use the information obtained from him or her for report and research purposes.

There are no risks to your child.

Should you want your child or the child in your care **not** to participate in the information collection, kindly indicate your decision below and return the letter to me not later than {DATE}.

I thank you for your willingness to allow your child or the child in your care to participate in this important activity.

Yours sincerely,

Mr. Luxolo Mlofane

I, (name and surname) ……, do give permission for (name child or the child in your care)……. to participate in the information gathering activity.

For any further issues related to the ethics of this project you can contact the HSSREC, Research Development, Tel: 021 959 4111, email: research-ethics@uwc.ac.za

Signature: (Signed)

APPENDIX C
Learner assent letter

Research title: Implementing productive practice in a grade 9 Mathematics class: A design research study.

Name and Degree	**Phone Number**	**E-mail**
Mr. Luxolo Mlofane, M.Ed. in Mathematics	063 353 8246	3375617@myuwc.ac.za

Dear Learner

I am investigating a way of teaching to see whether it will assist you to improve your results in examinations. You will not be taught topics that are different from those I am must teach. The only change that I will make is to, during our normal lessons, do exercises on work that have already been completed. I will, from time to time, write notes on, audio- and video record how you are working with normal (as in your textbooks) and other specially designed mathematical exercises on work that you have already completed. This information will be used by me to assist with the improvement of the mathematical activities so that you will be able to deal with problems similar or related to those in examinations.

Under no circumstances will your name be revealed or any image to identify of you be displayed when the information obtained from you is used for report and research purposes.

Kindly complete the part below to indicate that you understand the above and that I have explained it to you.

Yours sincerely,

Mr. Luxolo Mlofane

I, (name and surname) ……., herewith acknowledge that the conditions above has been explained to me, that I understand them and willingly participate in the project.

Signature: **(Signed)**

UNIVERSITY of the WESTERN CAPE

Department of Institutional Advancement
University of the Western Cape
Robert Sobukwe Road
Bellville 7535
Republic of South Africa

60 YEARS of hope, action & knowledge

10 December 2021

Mr. L Mlofane
School of Science and Mathematics
Faculty of Education

HSSREC Reference Number: HS21/10/21

Project Title: Implementing productive practice in a grade 9 Mathematics class: A design research study.

Approval Period: **09 December 2021 – 09 December 2024**

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology, and amendments to the ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report by 30 November each year for the duration of the project.

For permission to conduct research using student and/or staff data or to distribute research surveys/questionnaires please apply via:
https://sites.google.com/uwc.ac.za/permissionresearch/hom

The permission letter must then be submitted to HSSREC for record keeping purposes.

The Committee must be informed of any serious adverse events and/or termination of the study.

Ms. Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

Director: Research Development
University of the Western Cape
Private Bag X 17
Bellville 7535
Republic of South Africa
Tel: +27 21 959 4111
Email: research-ethics@uwc.ac.za

NHREC Registration Number: *HSSREC-130416-049*

APPENDIX E
RESEARCH APPROVAL LETTER

Directorate: Research

meshack.kanzi@westerncape.gov.za
Tel: +27 021 467 2350
Fax: 086 590 2282
Private Bag x9114, Cape Town, 8000 wced.wcape.gov.za

REFERENCE: 20220117-9055
ENQUIRIES: Mr. M Kanzi

Mr. Luxolo Mlofane
E653 Europe Street
Nyanga
Cape Town
7750

Mr. Luxolo Mlofane

RESEARCH PROPOSAL: IMPLEMENTING PRODUCTIVE PRACTICE IN A GRADE 9 MATHEMATICS: A DESIGN RESEARCH STUDY.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **17 January 2022 till 30 March 2022.**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Mr. M Kanzi at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services
Western Cape Education Department

Private Bag X9114
CAPE TOWN
8000

We wish you success in your research.

Kind regards,
Meshack Kanzi
Directorate: Research
DATE: 17 January 2022

1 North Wharf Square, 2 Lower Loop Street, Foreshore, Cape Town 8001
Private Bag X 9114, Cape Town, 8000
Safe Schools: 0800 45 46 47 tel: +27 21 467 2531
wcedonline.westerncape.gov.za

APPENDIX F
School Management Team consent letter

Private Bag X17, Bellville, 7535

South Africa

Tel: 021 959 2861

Fax: 021 959 3358

Research title: Implementing productive practice in a grade 9 Mathematics class: A design research study.

The Research Team:

Name/Degree	Phone Number	Department	E-mail
Mr. Luxolo Mlofane, M.Ed. in Mathematics	063 353 8246	School of Science and Mathematics at UWC	3375617@myuwc.ac.za

Project worker/investigator: Mr. Luxolo Mlofane

Dear School Management Team (SMT)

The LEDIMTALI project intends to implement a project to improve the examination results in Mathematics in your school. The project is explained in the attached information sheet.

The teacher or a project worker will, from time to time, write notes on, audio- and video record how learners are working with normal (as in their textbooks) and other specially designed mathematical exercises on work that they have already completed. This information will be used by the project to assist with the improvement of the mathematical activities so that learners are able to deal with similar or related problems in examinations.

Learners will also be required to periodically complete a questionnaire on their experiencing of the teaching of Mathematics. The questionnaire will be completed under the supervision of an experienced project worker. The learner has the right not to participate and may at any time withdraw from completing the questionnaire. Under no circumstances will the name be revealed and learners will not be asked to write their names on the questionnaire. Furthermore, no image to identify learners will be displayed when the information obtained from them is used for report and research purposes.

There are no risks to learners.
Should you **not** want learners in your school to participate in the information collection, kindly indicate your decision below and return the letter to the project worker note later than {DATE}.

We thank you for your willingness to allow learners in your school to participate in this important activity.
For any further issues related to the ethics of this project you can contact the HSSREC, Research Development, Tel: 021 959 4111, email: research-ethics@uwc.ac.za

Yours sincerely
Mr. Luxolo Mlofane.

Signature: **(Signed)**