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Beginner Physical Sciences Teacher's Implementation of Problem-Based Learning in Promoting Creativity as a 21st-Century Skill on Learners: A Case Study

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***Abstract*—**This study investigated how one beginner Physical Sciences teacher implemented Problem-Based Learning (PBL) strategy in the teaching and learning of Particulate Nature of Matter (PNM) in the Grade 10 classroom. PBL was implemented to explore how it can promote a 21st-century skill of creativity and enhance understanding of PNM. This study was guided by theoretical framework of Social Interdependence Theory (SIT). This exploratory qualitative case study was conveniently conducted in the North West province, South Africa, where one Physical Sciences teacher was purposefully sampled. A self-developed open-ended questionnaire, portfolio and individual semi-structured interview were used as the methods of generating data for this study. The results show that the participant of this study had no prior knowledge of utilising PBL in the teaching and learning of PNM before the Teacher Professional Development (TPD) programme, no knowledge of creativity as a 21st-century skill, and a successful PBL implementation post TPD to promote creativity.

***Keywords*—**Beginner teachers, physical sciences teachers, problem-based learning, 21st-century skills, creativity skill, particulate nature of matter.

I. Introduction and Background

THE purpose of this study was to explore one beginner Physical Sciences teacher's implementation of PBL to promote creativity as a 21st-century skill on learners while teaching the topic PNM. It is becoming increasingly clear that content knowledge must be partnered with some 21st-century skills in order to prepare learners to thrive in today's ever-changing interconnected world [1], [2]. 21st-century skills are core competencies for effective learning, participating and succeed in the world today [3]. One set of such skills is the 4Cs, which include are communication, collaboration, critical-thinking, and creativity [4]. It is noteworthy to mention that this study forms part of a larger project which explored the promotion of the 4Cs by more than one beginner Physical Sciences teachers. However, the focus of this study is on the promotion of creativity by one beginner Physical Sciences teacher.

There are various definitions of creativity, rather than only a unitary definition. Creativity is defined as offering new perspectives, generating novel and meaningful ideas, raise new questions, and coming up with novel solutions to ill-defined problems in specified contexts of value [5], [6]. To [7], creativity is the ability to refine existing or generate new ideas; to be open-minded and courageous to explore; work creatively with others; and creative and innovative production. Creativity is seen as the foundation of higher achievements such that learners are enabled to go beyond existing solutions through critical-thinking [4], [8]. "Reference [9] states that creativity has been considered as one of the important skills that must be mastered and is the key to effective learning in the 21st-century." The importance of creativity skill is to ease the process of managing the complexities of globalization and social justice [10]. Creativity is integral to teaching of science content knowledge [2].

The South African Physical Sciences curriculum aims to produce learners who can: "identify and solve problems and make decisions using critical and creative thinking; work effectively as individuals and with others as members of a team" [11]. It is clear that the aims of the South African curriculum and the focus of this study, being the 21st-century skill of creativity, are undeniably aligned. This skill of creativity is looked at during the teaching and learning of the broad topic – Particulate Nature of Matter (PNM). PNM was selected since it is one of the fundamental concepts in Physical Sciences. PNM is an abstract topic which presents multiple teaching and learning challenges [12]-[14]. Teaching challenges are prevalent on beginner teachers [15]. Reference [16] says that beginner teachers have little or no mastery experience, and often teachers who have less than two years of teaching experience. This study adopts a definition by [17] that "beginner Physical Sciences teachers refer to those who have recently started teaching such that they have five years or less, and possess relevant teaching qualifications such as a Bachelor of Education (B. Ed), B. Ed Honours and Post-Graduate Certificate in Education (PGCE)."

Unanimous with the current study, [2], [18], [4] state that PBL is one of the relevant teaching and learning strategies which are more likely to enhance learners' creativity since it emphasizes personal experience. PBL is an influential teaching and learning strategy for inquiry-based learning in which learning begins with an authentic ill-structured problem with more than one solution [19], [20]. Moreover, PBL has proven to be an effective instructional pedagogy that inherently engages learners in meaningful learning through facilitation [21]. As in the PBL process, creativity is more about allowing learners the freedom to make mistakes while thinking divergently rather than accuracy and the solution.

Since beginner science teachers are considered to possess inadequate knowledge of the subjects they teach [22], their

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knowledge needs to be enhanced and expanded [23]. Therefore, a TPD intervention was administered for beginner Physical Sciences teachers to facilitate effective teaching of PNM through PBL to promote creativity. The following research question guided this study:

- How does one beginner Physical Sciences teacher's PBL implementation promotes creativity as a 21st-century skill on the learners while teaching PNM?

II. Literature Review

The theoretical framework which underpins this study is social interdependence theory (SIT). SIT was proposed by [24] for the purpose of explaining the effect of cooperation and competitiveness on small group functioning. Reference [25] defines SIT as a shared influence between individuals during a small group learning. Various scholars [26], [27] have reported a success of SIT implementation in school education. "Social interdependence theory maintains that when one person's goals are structured cooperatively with another, motivation increases resulting in a sense of responsibility to contribute to the group, and achievement improves as individuals interact in ways that promote each other's success" [28]. PBL is one of the learning approaches of which the foundations are premised in SIT [29].

PBL is a teaching and learning strategy which allows learners to work on a problem without being prepared and having adequate knowledge to solve that problem [30]. PBL is based on learners working in small cooperative groups and stages of cooperative learning, therefore cooperative learning is involved [31], [32]. PBL is the best approach that can be utilised across all disciplines [33], including education for any school subject [34]. Primarily, the goal of PBL as a teaching and learning strategy is to enhance small group learning through solving PBL problems [35]. One the PBL characteristics which is explored in this study is a*ssumption of different roles by both the teacher and learners* during PBL implementation where the teacher is a facilitator responsible for designing and identifying problems that are complex and vague thus encouraging the learners in a group to inquire about them [36], and learners take up different roles such as being the group-leader, scribe and only group member; however, each member in the group has an opportunity to present the solution to the rest of the group with the supporting material [37]. A PBL assessment must comprise learner-based and teacher-based assessments promoting 21st-century skills within the learners [37]. These two assessments attempt to ensure that teachers and learners are looking at and for same goals [38]. As mentioned earlier, PBL is considered relevant to promote creativity.

Creativity may result in many innovations if acquired [39]. According to [8], "the creative attitude includes characteristics and capabilities that condition wise actions and thinking, such as sensitivity, the ability to identify problems, an openness to problems and ambiguity, reflection in the form of constant surprise at the world, cognitive curiosity and critical thinking, the ability to draw comparisons and make decisions, and the motivation to persistently seek for solutions and improve upon them." Reference [40] argues that the future of mankind depends on creativity skill. "Teachers' promotion of creativity in classrooms can be significantly influenced by their good knowledge and understanding of the concept and their awareness about effective strategies for its integration" [41]. Creativity can be assessed by how learners apply the newly acquired knowledge to real-world situation [42].

In Kota-Kinabalu (Malaysia), [43] conducted a mixed methods study aimed to determine whether PBL helps in fostering 'scientific' creativity among grader 5 science learners who were purposefully selected. Through creativity tests and open-ended questionnaires, [43] found that learners' creativity was improved during PBL implementation, thus improving science content knowledge. The findings of their study also reveal that learners found PBL fun, interesting, easy as well as a practical way of gaining and advancing knowledge of science. Reference [44] conducted a quasi-experimental study with two groups of 28 grade 10 learners in each group in Central Java, Indonesia. The findings of their study show that creativity was more enhanced on the experimental group than the control group.

Scholars have used the terms, novice teachers, new teachers, neophyte teachers, newly qualified teachers, and beginner teachers (which is adopted in this study) interchangeably. Although the definition of beginner teachers varies, the idea is mainly about the teachers who have recently qualified from high institutions and entered the education system to practice. "The first few years in the teaching profession are usually demanding" [45]. There are many issues regarding beginner teachers. Beginner teachers are most likely to use teaching approaches to which they were exposed that might have worked for them as learners [46]. Reference [47] argues that beginner teachers subject the learners they teach to less than quality learning hours, which eventually has undesirable outcomes. A quasi-experimental study by [48] examined the entry-level capability of 106 beginner science and technology teachers which showed potential benefits to conducting a TPD intervention for beginner teachers. According to [49], beginner teachers' instructional strategies must be improved through a TPD intervention programme. Reference [50] conducted a study which ran a TPD in facilitating small-scale implementation of inquiry-based teaching in various secondary schools in South Africa. One of the significant findings by [50] was that the teachers acknowledged changing their instructional practices and gaining greater subject knowledge as well as improved teaching skills as the TPD was directly linked to their daily experiences.

The National Senior Certificate examination report 2019 [51] shows a decline on the number of learners enrolling for Physical Sciences in the past 5 years in the North West Province. The PNM is one of the fundamental concepts in science for one to understand subsequent topics in Chemistry. Reference [52] posits that learners have difficulties in understanding various chemistry concepts especially PNM and it is a great concern in Malaysia. Since [53] pointed out that learners' PNM originates from daily experiences and

classroom instruction, this study proposes the utilisation of PBL which allows integration of real-life and class-taught content.

III. Research Methodology

A. Research Design

A qualitative research method was employed to determine how one beginner Physical Sciences teacher's PBL implementation promotes creativity as a 21st-century skill on the learners while teaching PNM after a TPD intervention. An exploratory qualitative case study approach was utilised. According to [54], limitations of case studies include that the findings cannot be generalized but may be explored within similar contexts, and this also applies to this study.

B. Site Selection, Sampling Technique, and Sample

First, this study was conveniently conducted in one of the four districts of the North West province, South Africa, due to its geographical proximity and accessibility to the researchers. Then purposeful sampling was utilised to identify study participants who possess particular knowledge being sought for [55], in this case, a beginner Physical Sciences teacher. In order to protect the confidentiality of the participant in this study, a pseudonym was utilised, and the participant was named Rebaone (25 years old female). Rebaone had 2 years teaching experience and possessed a B.Ed with specialisation in Physical Science and Life Sciences. Rebaone is teaching in a former 'Model C' secondary school. Former 'Model C' schools, usually in urban areas, perform better than other schools within the same educational district [56]. Rebaone was teaching Physical Sciences to two grade 10 classes of 27 learners each. During PBL implementation, Rebaone divided her learners into five groups where three groups had 5 members and two groups had 6 members.

C. Data Generation Instruments and Analysis

Data generation instruments used in this study include: a self-developed open-ended questionnaire, portfolio and individual semi-structured interview. Open-ended questionnaires were used to collect data in November/ December 2019.

The framework by [57] was used to analyse generated data. Analysis of open-ended questionnaire was done before the TPD. The TPD was tailor-made to the participants' needs as suggested by [58]. A one-day PBL TPD programme was conducted (January 2020) to enhance the use of PBL in order to promote 21st-century skills including creativity while teaching PNM. Moreover, during the TPD, participants were advised to view creativity as the ability to refine existing concepts or generate new ideas; to be open-minded and courageous to explore; work creatively with others; and creative and innovative production. After attending the TPD programme, participants were required to implement PBL and compile a portfolio documenting PBL observations in their classrooms (January to March) of which Rebaone was one of the participants. "Portfolios provide rich information regarding the curriculum and its implementation" [59]. The portfolio consisted of various sections; however, this study will only focus on: the teacher's and learners' roles during PBL implementation; 21st-century skill observed; teacher-based assessment rubrics; and details of what happened during the PBL lessons. The portfolio data were analysed using the Interstate New Teacher Assessment and Support Consortium (INTASC) performance standards scoring rubric adapted from [60], the teacher-based rubric was adapted from North-West University Faculty of Education Geography Department [61], the learner-based rubric was adopted from the University of Rochester Life Sciences Learning Centre [62] and [57] analytical framework. Finally, after data from questionnaire and portfolio were analysed, the participant was interviewed and data generated were analysed using [57] analytical framework.

TABLE I
Open-Ended Questionnaire

Background Data:
1. Age and gender:
2. Grade and subject taught:
3. Number of learners per class:
4. Number of years teaching Physical Sciences:
5. Tertiary qualification(s):
6. Specialisation(s):
7. Type of school:
Study Content Questions of the Questionnaire:
8. How do you describe your teaching of Particulate Nature of Matter concepts?
9. What teaching approaches do you utilise while teaching Particulate Nature of Matter? (List all of them)
10. Why do you use the teaching approach(es) stated at question 9 above?
11. What is your understanding of Problem-Based Learning?
12. What prior knowledge do you have of utilising Problem-Based Learning while teaching Particulate Nature of Matter?
13. What is the role of the teacher when utilising Problem-Based Learning?
14. What is the role of the learners when utilising Problem-Based Learning?
15. List five 21st century skills that you know.
16. Explain how you inculcate and develop the 21st century skills (if any) you mentioned in question 15 above in your learners.
17. Describe ways (if any) in which you inculcate your learners to apply 21st century skills on science principles and generalisation on new problems and situations.
18. Which concepts, in teaching of Particulate Nature of Matter have you used to instil 21st century skills?

Trustworthiness of generated data was ensured through an audit trail. An audit trail provides "a complete set of notes on decisions made during the research process, research team meetings, reflective thoughts, sampling, research materials adopted, emergence of the findings and information about the data management" [63] This was done with participant Rebaone to ensure trustworthiness of data generated. Credibility is the participants' involvement in the study findings to ensure the results of the study are true and credible [64]. In this study, the authors spent a prolonged time in the field and engagement with the participant and checked their interpretations with the participant to ensure credibility. Confirmability seeks to show authenticity of the findings reported and the interpretations linked to generated data [65]. Confirmability was achieved through applying a theoretical

framework and reporting the data using verbatim quotes.

IV. Results Presentation, Interpretation and Discussion

This section presents the results and discussion in attempt to answer the research question of this study:

- How does one beginner Physical Sciences teacher's PBL implementation promotes creativity as a 21st-century skill on the learners while teaching PNM?

Pre-TPD data were generated teaching and learning of PNM where Rebaone was asked to: 'describe her teaching of PNM', 'mention teaching strategies she utilises to teach PNM', and 'rationale for using those teaching strategies'. It is noteworthy to mention that pre-TPD results show that Rebaone did not mention PBL in the teaching and learning of PNM. The teaching and learning strategies mentioned by Rebaone to teach PNM include Demonstration; Direct instruction; Inquiry-Based Learning; Game-Based Learning; and Cooperative learning. Rebaone's rationale for the aforementioned strategies is "to promote learners' critical-thinking skill." When describing her understanding of PBL, it shows that Rebaone sees PBL as cooperative learning. Rebaone's response in verbatim is as follows: "PBL is a learner-centred approach whereby learners discover things for themselves and solve problems, involving group work and learners share ideas through cooperation." There are similarities between the Rebaone's understanding of PBL in this study and PBL description by [31], [32] who are of a view that PBL is based on cooperative learning. Surprisingly, these results show that Rebaone has partial understanding of PBL. This is surprising since Rebaone has never used PBL to teach. Although Rebaone has no prior knowledge of utilising PBL in the teaching and learning of PNM, she mentioned that she sees the teacher's role as the coach while seeing the learners' roles as effective self-monitors. It is interesting to note that Rebaone's knowledge of the PBL process regarding learners' and teachers' roles corroborates with the descriptions by [36], [37]. When asked to mention known 21st-century skills, Rebaone did not mention creativity but critical-thinking. Furthermore, Rebaone mentioned skills which were wrongly identified as 21st-century skills, i.e., listening, problem-solving, and self-direction. Unfortunately, these results indicate that Rebaone's knowledge of the creativity as a 21st-century skill is limited. It is difficult to explain these results, but it might be related to the fact that Rebaone's main focus is promoting critical-thinking skill. Therefore, this analysis urged emphasis on PBL and creativity as a 21st-century during the TPD programme to enhance better implementation while teaching PNM.

The rubric by [60] was adapted to assess the participant's portfolio. The rubric has three INTASC principles concerned in this study, namely: PBL implementation; 21st-centrury skills observed template; and assessment of learners' learning process and work. In assessing the aforementioned INTASC principles, data were sourced from aforementioned parts of the portfolio using the scoring criteria of 1-4, where 4 = Clear, convincing and consistent evidence; 3 = Clear evidence; 2 = limited evidence; 1 = No evidence.

PBL implementation is a principle which is concerned with the classroom practice. The portfolio parts that informed this principle were as follows: the teacher's role as the facilitator; and learners' roles within the group and as active participants. The indication checklist regarding this theme clarifies if the teacher: understands how learners should learn and develop; and provides a learning opportunity and environment that adheres to PBL approach to support learners' cognitive, social and personal development. In verbatim, Rebaone mentioned that: "I presented the PBL problem to the learners and allowed them to work in groups which adheres to the requirements of PBL approach. I constantly checked my learners' progress, guiding their thinking and assisting them with some of the questions asked. I was in charge of my classroom and kept good discipline on my learners. My learners understood their role during implementation." Rebaone understood how learners must learn and develop during PBL implementation. This finding corroborates [41]'s statement that a teachers' promotion of creativity can be influenced by their knowledge about effective teaching and learning strategies which in this study is PBL.

It is evident that learners were provided with the learning opportunity and an environment adhering to the PBL approach supporting learners' cognitive development regarding the content, and social and personal development regarding the 21st-century skills. Rebaone facilitated learning through PBL groups, putting responsibility on the learners, observing learners' interactions and asking probing questions. Rebaone's portfolio provided clear, convincing and consistent evidence of PBL implementation. When asked, 'what can you say about your teaching before and after the workshop?', Rebaone's response was: "Truly speaking, I will mostly tick to my old teaching strategies. But in some topics such as PNM, I will sometimes use PBL." Although this study's participant expressed that she will continue to use her usual teaching strategies to teach most topics, and only utilise PBL in some of the topics such as PNM, it is satisfactory because this indicates that there is a difference in their teaching after the workshop. This finding corroborates [50] who found that South African Physical Sciences teachers acknowledged that TPD improved their teaching approaches and content knowledge since it was directly linked to their daily experiences.

Regarding 21st-century skills observed, Rebaone observed creativity skill during PBL implementation, and mentioned that it was 'Good', on the comment section. Rebaone obtained a presented a clear, convincing and consistent evidence. This study acknowledges that creativity is a skill that may be difficult to observe and/or promote. As in the PBL process, creativity allows learners the freedom to make mistakes while thinking divergently rather than accuracy and the solution. Some of the various ways of observing creativity is presented by the generated theme, i.e., Ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions. During the interview, Rebaone was asked, "How could you tell that creativity as a 21st-century

skill was enhanced on your learners while utilising PBL?", and she said, "As much as I was facilitating and guiding the learners, they were always ahead and they were not afraid to make mistakes. And like I mentioned, their interest and energy for the task were high." This result is in line with [8], who states that creative attitude shown by learners includes cognitive curiosity and critical thinking, the ability to draw comparisons and make decisions, and the motivation to persistently seek for solutions and improve upon them. The findings of this study regarding promotion of creativity through PBL are in corroboration with Malaysian [43] and Indonesian [44] studies.

The assessments section in the portfolio was about the evaluation learners' learning process. This section was appraised using 'work' INTASC principle on the rubric. The indication checklist scrutinised the following: use of [61] teacher-based rubric to evaluate learners' work; and use of [62] learner-based rubric for self-evaluation as a PBL group. The 'identification and recommendation of possible solutions for the problem' is a criterion which concerns this study from the rubric by [61]. This criterion's quality levels are described as follows: excellent range of 12-20: a complete and exceptionally well formulated solutions and recommendations were made for the problem; good score range of 11-15: complete and well formulated solutions and recommendations were made for the problem; efficient score range of 5-10: only certain solutions and recommendations is applicable to the problem; inefficient score range of 1-4: very weak formulated solutions and recommendations were made. Rebaone deemed her learners excellent. The Family Secrets' rubric assessed whether learners are able to 'develop multiple solutions to major problem(s). This was in relation to the creativity skill. The rubric by [57] assesses this aspect in the following levels: 1-Limited; 2-Developing; 3-Proficient; 4-Advanced; and 5-Exemplary. Rebaone's learners considered themselves *3-proficient* in this aspect. As suggested by [38], Rebaone and her learners were assessing the same aspect regardless of the rubrics being teacher- or learner-based. In summation of this principle, Rebaone's data were clear, convincing and consistent.

V. Conclusion

The results of this study showed how Rebaone was able to implement PBL teaching and learning strategy to promote a 21st-century of creativity. This study further amplified how (beginner) Physical Sciences teachers can be equipped with PBL in promoting creativity. This study further amplified how (beginner) Physical Sciences teachers can be equipped with PBL in promoting creativity. The findings of this study corroborate submissions made by [28] about positive interdependence as indicated in the literature review section. This study produced results which corroborate the findings of a great deal of the previous work in this field. It can also be concluded that the way in which one beginner Physical Sciences teacher implements PBL to promotes creativity on the learners while teaching PNM is highly satisfactory.

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