

# TEACHER LEADER AGENCY FOR SCIENTIFIC LITERACY LEVEL THAT MEETS LEARNERS' ADVANCED SKILLS AND SPECIALISED KNOWLEDGE DEMANDS

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*Collectively there has been this upwell saying we need more learners to do science and engineering and mathematics. But the solution needs to be much more complex than a political solution...I understand the political reasons when you get physicists from a number of universities worried that they are not getting enough learners and put pressure on the government to do something about it. Then it comes back to, let's increase the emphasis on the content or do something about the school curriculum (Aubusson, 2011, p. 236)*

**ABSTRACT**– Advanced skills and specialised knowledge in the science, technology, engineering and mathematics (STEM) fields play a vital role in supporting the growth of national economies. However, aspirations to achieve scientific literacy that translates in enough learners who can pursue further studies in the STEM fields are not being satisfied. A number of challenges have rendered the realisation of this goal elusive. In this paper, we conducted a literature review to identify some of the challenges in high school science teaching and learning that resulted in few learners achieving the level of scientific literacy that would enable them to pursue careers in the STEM fields. Additionally, the concept of teacher leaders in the context of communities of practice and professional development was used as framework to discuss ways of improving the visibility of science by ensuring high levels of scientific literacy in learners who graduate from high school. In summary, the findings place science teacher leaders at the forefront of efforts to develop scientifically literate learners in sufficient numbers to meet societal needs. The science teacher leaders' agency is strategically positioned to influence the levels of scientific literacy that high school learners achieve.

**Keywords:** advanced skills; agency; scientific literacy; specialised knowledge, teacher leaders

## 1. INTRODUCTION

Scientific literacy is a constituent of STEM literacy and significantly contributes to the attainment and development of advanced skills and specialised knowledge in the discipline. The urgent call for educational reform in developed and developing nations has brought about different policies and practices of which STEM is a major part. STEM fields have received credence partly due to the current career gap because many are steering away from a career in mathematics and science (Watt, Richardson & Pietsch, 2007). There are also a number of careers requiring a strong background in science, technology, engineering and mathematics (STEM) of which there are a limited number of learners willing to pursue (National Research Council, 2011; Zavadsky & Garby, 2012). The International Labour Organisation (2011) reported that 77 million youths around the world are unemployed because they cannot meet the technological demands, which is the trend all over the world today. The challenges thus, make it imperative for research in the field in order to achieve scientific literacy that will enable learners to pursue further studies in STEM. Again, STEM pedagogy is trans-disciplinary in nature, it is an integration of four content areas (science, technology, engineering and mathematics) that are inquiry-based, project-based and set in real-world applications, that present learners as active participants in building new content understanding (Crippen & Archambault, 2012). STEM education is

all encompassing, as it connects the learner with the world and does not confine learning the four walls of the classroom (Tsupros, Kohler & Hallinen, 2009)

However, the contribution of teacher leader practice in STEM education cannot be overstretched; studies have shown the interconnectivity of leadership, teaching, learning and school culture (Hallinger & Heck, 2010; Leithwood & Jantzi, 2008). Teachers are accountable for improving teaching and learning not just as teachers but also as teacher leaders (Danielson, 2007; Harrison & Killion, 2007). The concept of teacher leadership has gained momentum in recent times as a probable means by which educational reform and instructional improvement can be accomplished. Teacher leaders are expected to perform various duties by directing the entire school toward higher standards of achievement and recognition of individual responsibility for school reform. STEM teacher leaders work collaboratively to assist in the development of teachers and pedagogy in the STEM disciplines, such as science, technology and mathematics. In recent research, Leana (2011) indicates that the strategy for improving individual teachers' knowledge and skills (human capital) are unlikely to affect positive change unless educators have the capacity to exercise collective responsibility. Therefore, the challenge is in not only attracting and retaining high-quality STEM teachers but also building their collective capacity and responsibility for instructional improvement and educational reform. Discussions on STEM cannot be overemphasised because its skills and artefacts 'invade' all realms of life, the long-term viability and well-being of South Africans hinge on it. As a result, the pool of potential scientists, engineers, health practitioners and future teachers of mathematics and science are severely limited. Consequently, this restricts South Africa's ability to be internationally competitive and impedes its ability to provide the required infrastructure for the wellbeing of the majority of her people.

## 2. METHODOLOGY

This paper is a literature study that sought to answer the question, *how can a teacher leader agency contribute to levels of scientific literacy that meet learners' advanced skills and specialised knowledge demands?* Current literature that directly addresses the concept of teacher leaders in science teaching is scarce. However, the concept of teacher leaders is one of the undergirding features of democratic and participatory instructional leadership practices (Higgins & Bonne, 2011). The agency of teacher leaders in science education could be deciphered from the literature on professional development and communities of practice. We found the article written by the Wellcome Trust (2015) to be useful in providing insights on the roles of teacher leaders in science. We conducted a literature search on 'teacher leader' and 'scientific literacy' as conceptual frameworks that guided the pursuit of the research question. The literature was sifted to develop arguments on what constitutes the level of scientific literacy that meets the demands of advanced skills and specialised knowledge as well as the challenges that impede the required levels of scientific literacy in learners. Literature on the role of science teacher leaders in providing instructional leadership that translates in improved learner outcomes was also consulted. Finally, the arguments were utilised to motivate the role that teacher leaders play in improving learner achievement in science.

## 3. SCIENTIFIC LITERACY

Initiatives to promote scientific literacy under the general drives to achieve STEM literacy for all learners in order for them to participate meaningfully in the global economy are more pronounced in the 21<sup>st</sup> century (National Science Board, 2007). Scientific literacy has successfully joined the ranks of numeracy and literacy as important goals of education. The initiatives are reflected in school science curriculums by encompassing a vision to achieve scientific literacy for all learners (Martinez-Hernandez, Ikpeze & Kimaru, 2015). Learning science is closely intertwined with developing scientific literacy. Tytler, Haslam, Prain and Hubber (2009, p. 1) propound that, "...learning science entails learners learning the literacies of the scientific discourse community, which uses a wide range of subject-specific and general representational tools to construct and justify evidence-based claims about the natural world."

The initiatives to achieve scientific literacy for all learners have gained support from stakeholders such as politicians, academics and world organisations (Clothey, Mills & Baumgarten, 2010). The 'science for all' campaigns as a strategic goal for sustainable development as promulgated by UNESCO (2004) are an example of the efforts to prepare scientifically literate citizens. Commenting on the 'science for all' initiatives, Aubusson (2011) observes that the emphasis of school science education is to achieve scientific literacy for all learners. These new goals for science education became major themes in curriculums from the 1980s (Hofstein, Eilks & Bybee, 2011). Secondary school science is positioned strategically as the final stage of schooling to give a measure of the level of scientific literacy attained by learners upon leaving school.

The measure of scientific literacy attained by learners when they finish secondary school is closely linked to the definitions of scientific literacy, which are themselves rooted in the goals of science education. Traditionally, the introduction of science in the school science curriculum was to prepare learners for further science studies at tertiary education (Holbrook, 2009). After completing school, learners would be in a position to pursue science related careers. Accordingly, the measure of scientific literacy achieved would be determined by the number of learners who would qualify to be placed for further education in science. However, not all learners harbour career interests for science or will pursue careers in science related fields (Hofstein *et al.*, 2011). In fact, relatively few of the learners who finish secondary school enter STEM related fields (Dillon, 2009). This reality has positioned issues of the relevance of science content taught in schools in the fray of scholarly debates (Holbrook & Rannikmae, 2009). The science relevance debates have also influenced the development of science curricula after the realisation that not all learners need to learn the abstract systems of concepts and theories of science in order to be functional citizens (Holbrook & Rannikmae, 2009). Stakeholders however maintain that it remains important that science education is made available for all learners.

The meaning of scientific literacy keeps evolving but Holbrook (2009) notes that the emphasis of the interpretation is moving away from scientific literacy as the understanding of the system of abstract scientific concepts to relevant science that integrates socio-scientific issues. Despite the recognition that not all learners will pursue careers in STEM fields and movements to make science more relevant by integrating socio-scientific issues, the need for learners to demonstrate an understanding of the scientific concepts has not been made irrelevant. Learners need to demonstrate an acceptable level of conceptual understanding of science in order for them to be placed and selected successfully for further studies for specialised and advanced skills in the STEM fields. Being able to decide on personal and social processes only is not sufficiently scientifically literate to pursue careers in the STEM fields. Consequently, the level of scientific literacy that include understanding the system of scientific concepts and theories garners renewed relevance against a backdrop in which an education to develop human capital is emphasised, more so in the STEM fields where shortages are perceived (Clothey *et al.*, 2010). The development of skilled human capital has been underscored as a way to stimulate the growth of economies in developing countries (Fensham, 2013). Clothey *et al.* (2010) observe that governments of developing countries who compete for foreign capital to support economic growth should also provide more skilled labour, which includes individuals who are trained in advanced and specialised skills in the STEM fields. As a developing country, the urgent need to improve STEM human capital and increase the level of scientific literacy of the learners graduating from secondary school is not strange to South Africa.

#### **4. LEARNING CHALLENGES IN SCIENCE EDUCATION**

Although developing scientifically literate citizens has been identified as one of the pillars to support global economies, it has not been easy for the different education systems to achieve this goal. Attempts to develop learner scientific literacy faces a number of challenges. Research highlights a number of challenges that stand in the way of improved learner outcomes in science education (Martinez-Hernandez *et al.*, 2015; Sullenger, 2007; Cheung, 2007; Onwu & Stoffels, 2005). Martinez-

Hernandez *et al.* (2015) observe that science education in some developing countries is in a deplorable state. Learning problems and poor learner outcomes have often been associated with unsupportive teaching and learning environments associated with large classes, inadequate teaching facilities and resources (Onwu & Stoffels, 2005). The teaching facilities and resources include science laboratories, equipment, materials and technological facilities.

Some of the unsupportive teaching and learning environments are inherent to teacher professional identities. Poorly trained teachers and teachers who are unwilling to embrace changes associated with instructional strategies for improved learner achievement man some of the science classrooms (McPhearson, Gill, Pollack & Sable, 2008; Martinez-Hernandez *et al.*, 2015). Language has also been identified as one of the learning barriers in science classrooms. Learners need appropriate literacy knowledge and skills in order to learn science (Sullenger, 2007; Martinez-Hernandez *et al.*, 2015). In South Africa, science has been observed being taught in first and second additional languages (Webb, 2009). Secondary school science learners need to have developed prior knowledge and skills in science and mathematics as well as learning tools such as independent learning. Failure to have acquired the necessary prior knowledge is a barrier to effective learning and the development of scientific literacy levels upon completing school that enables learners to acquire advanced and specialised skills through further study.

McPhearson *et al.* (2008) assert that there is a general tendency of fear and aversion to science that may be a result of the observed poor learner achievements and barriers to science literacy. It is reported that many learners shy away from choosing STEM subject electives in school that will enable them to pursue further studies in the fields (Donnelly, McGarr & O'Reilly, 2011). The other reported reason that discourages learners from choosing science among the electives in the science curriculum is that teachers do not use instructional strategies that respond to the learners' preferred ways of learning (Sullenger, 2007). Failure to attend to the preferred learning styles of learners causes them to experience science negatively and they become discouraged (*ibid*). Hofstein *et al.* (2011) echo the preceding point upon observing that recent reports concur that the content of school science and the related instructional practices fail to kindle learners' interest in science.

A lack of motivation and interest to study physical sciences is a generally observed trend in learners in the senior phase of secondary education and beyond (Donnelly *et al.*, 2011). The authors recommend that inquiry-based instructional strategies, problem-solving, assessment of practical work and the integration of information and communication technology (ICT) should be emphasised. It is also important to point out that science teaching and learning has inherent instructional practices that can stimulate learner interest, which are not always effectively exploited. Scientific inquiry in the form of practical work is renowned for its potential to develop learners' appropriate attitudes for science learning such as interest, curiosity, independent learning and practising science as a human endeavour (Toplis, 2012). Scientific inquiry through practical work involves a display of conceptual and procedural understanding skills and knowledge, which enhances scientific literacy. Learning problems in science are usually contextual and teachers should be able to identify and attend to them accordingly.

## 5. TEACHER LEADERSHIP

The conviction and challenges of national security and economic competitiveness of the nation depends on a highly qualified science, technology, engineering and mathematics (STEM) workforce. It also depends on the equally important need to be inclusive of the diverse demographic groups of students. It has placed tremendous demands on teachers to step into new leadership roles, contexts and given them responsibilities that are inclusive of diversity and equity. Teacher leadership has been defined by many experts and can be formal or informal. According to Reeves (2009, p. 85), teacher leadership is "the act of influencing the classroom practices of professional educators". Teacher leadership can support the professional learning of others and the progress of the school. The expansion of professional learning communities has given teachers opportunities to become leaders

(Gordon, 2010). When teachers volunteer to help each other learn, leaders emerge from within the community.

Regardless of the type of leadership or guidance, every effort must be directly applied to instruction and curriculum within the school. Teacher leaders should strive to improve instruction in their school and across the district. "Teacher leadership is not an option; it is necessary" (Kinney, 2008, p. 20). Teacher leadership can thus be seen as an essential requirement to design and offer equitable curricular and instructional decisions to ensure science learning for diverse students in a robust manner. Furthermore, teacher leadership is not isolated to just individual teacher learning but also involves the peer learning for capacity building. Thus, teacher leadership is "a potentially powerful strategy to promote effective, collaborative teaching practices in schools that lead to increased student achievement, improved decision making at the school and district level, and create a dynamic teaching profession for the 21<sup>st</sup> century" (Teacher Leader Exploratory Consortium, 2011, p. 3).

The success of professional development depends on effective teacher learning especially for STEM professional development and learning to be effective. Pea and Wojnowski (2014, pp. 6-7) noted that it included "active learning on the part of students and teachers, content and pedagogy, duration of activities, reform--based strategies, and collaborative practices". In recent times, the role of communities of practice has become a dominant professional development initiative (Darling-Hammond & Richardson, 2009; Lieberman & Mace, 2008). Communities of practice are viewed as emergent, self-reproducing and evolving entities that are distinct from and frequently extend beyond, formal organisational structures, with their own organising structures, norms of behaviour, communication channels and history (Lave & Wenger, 1991). Professional development is an inherent aspect of educational reform and classroom practices. However, effective professional development is one that is continuous (Kriek & Grayson, 2009). The continuity of professional learning is facilitated through social interactions such as those that occur within communities of practice. Teacher leaders provide the influence and guidance that are essential for effective teacher and student learning (Loucks-Horsley, Stiles, Mundry, Love & Hewson, 2010).

This policy shift towards a more democratic and participatory decision-making process in schools offers the possibility of opening up the space for the emergence of teacher leadership. Williams (2011) points out that the educational policies rooted in the democratic principles as envisaged the South African constitution create a space to implement distributed leadership. Consequently, the field of Education Leadership and Management in South Africa, determined by the Department of Education, emphasises "participative, 'democratic' management, collegiality, collaboration, schools as open systems and learning organisations, and, importantly, site based management" (Van der Mescht, 2008, p. 14). In its simplest form, teacher leadership can be described as a model of leadership in which teaching staff at various levels within the organisation have the opportunity to lead (Harris & Lambert, 2003). The main idea underpinning the preceding view of teacher leadership is that leadership is not individual or positional. Instead, a range of people can participate in this group process.

In the context of STEM, a teacher leader's job title may include teachers on special assignment, coordinators, supervisors, instructional coaches, consultants, curriculum developers and instructional specialists. STEM teacher leaders also serve at the school and district levels which may at times include modelling lessons for teachers, planning lessons with the teachers and setting up, refurbishing and/or managing instructional materials (Harlen & Allende, 2008; Higgins & Bonne, 2011). It may also include planning and conducting professional development, selecting instructional materials, writing assessments, coaching teachers facilitating data-based decision making and assessing and revising the curriculum (Firestone & Martinez, 2008). However, in South Africa, these practices are not fully actualised. Teacher leadership practice is still within the confines of the classroom despite the policy that advocates for distributed leadership (Williams, 2011).

## 6. TEACHER LEADER AGENCY IN SECONDARY SCHOOL SCIENCE

Milne, Scantlebury and Otieno (2006) describe teacher agency as the ability to act under the given school contextual settings. Teacher leaders in science may not be formally appointed but are recognised by their desire and ability to take action and ensure that learner achievement is improved (DiRanna & Loucks-Horsley, 2001). DiRanna and Loucks-Horsley (2001) further point out that teachers need to have been empowered at some stage in order for them to display a teacher leader agency that is characterised by confidence in what they do. One way of empowering science teacher leaders is through targeted professional development to develop the necessary knowledge and skills (Yow & Lotter, 2016). DiRanna and Loucks-Horsley (2001) propound that science teacher leaders are not born but that they are made. Accordingly, Yow and Lotter (2016) assert that the development of teacher leaders in science should be supported and cultivated. The Wellcome Trust (2015) affirm that teacher leaders in science should be experts who have a deep understanding of scientific concepts, are confident in the use of scientific vocabulary and know how to research science topics and teach learners to do the same.

The teacher leaders in science should also possess the appropriate pedagogical knowledge to know when to use strategies such as inquiry-based instruction, practical activities, out of classroom learning, group work, problem solving, technology assisted instruction and effective formative assessment (Klentschy, 2008). Higgins and Bonne (2011) emphasise that teacher leaders can effectively support reform goals in education such as achieving high levels of scientific literacy, as advocated for in this paper. The Wellcome Trust (2015) compiled a summary of teacher leader tasks in science. Teacher leaders develop a whole school science vision, which is supported by a mission that comprises instigating initiatives, ensuring continuous teacher learning, monitoring progress and ensuring learner achievement. However, it is only in schools where the leadership values science that the teacher leaders are able to develop a whole school vision for science (Wellcome Trust, 2015). Teacher leaders' agency thrives in school cultures that embody collaboration, trust, professional learning and reciprocal accountability (Copland, 2003). Teacher leaders are tasked with developing the school's science curriculum and encourage more learners to choose science subject electives from the school curriculum.

Science teaching and learning can be resource intensive therefore, teacher leaders should be able to source and manage materials and facilities. An important duty of teacher leaders is providing support for instructional improvement (Louis, Dretzke & Wahlstrom, 2010). Teachers can exercise influence in various areas of science teaching that results in improved learner achievement. A teacher may display an effective leadership agency in mobilising resources and materials. Some teachers may lead others in using technology to support science teaching and learning. Some teachers may lead others in using innovative instructional strategies such as inquiry-based practical work. Some teachers may lead others in the practice of effective assessment practices. The Wellcome Trust (2015) underscores the role of teacher leaders in science to raise the standards for learners. Standards can be raised by using the results of monitoring teaching and learner achievement to plan for better science teaching and learning. Accordingly, teacher leaders in science influence others to teach science better, facilitate and lead discussions in departmental or subject meetings to share ideas and skills that are based on current developments and trends in science teaching and learning (Firestone & Martinez, 2007).

## 7. DISCUSSION

The work of teacher leaders to improve the scientific literacy levels is strategically positioned amidst an upsurge of calls to urgently develop human capital in the STEM fields. Human capital development in STEM fields is considered one of the pillars that must support the global economy and stimulate growth in developing countries (Aubusson, 2011). This paper focused on scientific literacy, defined holistically as the possession and understanding of abstract concepts in science and perspectives in science and technology that can be applied in personal life and other processes in society (Holbrook, 2009). It is through this aforementioned level of scientific literacy that learners can be successfully

selected and placed in tertiary institutions to study for specialised and advanced skills in the STEM fields. Despite the impetus supported by governments, world bodies, academics, politicians, scientists and other stakeholders to improve national scientific literacy levels, schools have not been able to satisfy this need by way of quality and quantity (Clothey *et al.*, 2010). We contend that science teaching and learning should occur as part of a wider project to position learners for further education in STEM fields.

Science teaching is not without challenges (Martinez-Hernandez *et al.*, 2015). The challenges in developing countries range from overcrowded classrooms, a lack of resources and facilities for effective science teaching and learning to teacher professional identities that do not adequately support learner achievement. One way in which the incompatible nature of teacher professional identities is evidenced, is the continued use of teacher-centred instructional strategies. The use of teacher-centred instructional strategies might be an indication of much deeper insufficiencies in science content and pedagogy mastery. Some of the challenges that result in learning problems and reduced levels of scientific literacy have their roots in poor language skills, poor development of prior and prerequisite knowledge and skills, competing worldviews and a failure to attend to the learners' preferred ways of learning (Martinez-Hernandez *et al.*, 2015; Sullenger, 2007). However, this paper sees the potential of science teacher leaders as custodians of science teaching and learning to work through the challenges and achieve high levels of scientific literacy by learners. A teacher leader agency that is characterised by professional attributes for improving science teaching and learning makes the achievement of high levels of scientific literacy in learners a realistic goal. We surmise that the resurgence of teacher leadership agencies is a way of sustaining communities of practice and continuous teacher learning.

Teacher leaders in science are empowered individuals through targeted professional development who are sufficiently equipped with deep scientific conceptual understanding, pedagogical knowledge and knowledge for effective incorporation of ICT in the classroom (Loucks-Horsley *et al.*, 2010). The teacher leaders should be able to develop the whole science vision and lead by taking initiative to make science visible and raise the levels of scientific literacy for learners (Wellcome Trust, 2015; West-Burnham, 2010). We should be asking ourselves how many secondary schools operate without a vision in science. To improve learner achievement, teacher leaders should actively participate in modelling lessons for teachers, planning lessons with teachers, setting up, refurbishing and/or managing instructional materials, planning and conducting professional development, selecting instructional materials, writing assessments, coaching teachers, facilitating data-based decision making, and assessing and revising the curriculum. The aforementioned roles are some of the activities that characterise continuous teacher development (Rout and Behera, 2014; Kafyulilo, 2013). Science and teacher leadership are rooted in specialist expertise and science teacher leaders are well-positioned to provide expert support in the classroom. Considering the potential of a robust teacher leader agency to improve science learning, we argue that the vacuum in instructional leadership created by its absence leads to ineffective science classroom practices. Teacher leaders are well positioned to influence learner achievement because they are directly involved as the classroom practitioners. It is apparent that in order for learners to be successfully placed in tertiary institutions to pursue training for advanced skills and specialised knowledge, they need to meet the minimum requirements of scientific literacy. This paper contributes to some of the possible solutions in the quest to increase the number of students in this regard by harnessing the potential of a teacher leader agency.

## 8. Conclusion

This paper is a motivation and recommendation for teacher leaders to activate their agency for learner achievement that translates into a level of scientific literacy for the learners' placement in tertiary institutions to pursue studies in STEM fields. Elevating the levels of scientific literacy is a noble vision for science and responds to 21<sup>st</sup> century global needs to develop STEM competent human capital to stimulate economies. The quote from Aubusson (2011) at the beginning of this paper suggests that in

order to tackle the problem of poor levels of scientific literacy in learners upon completing school, much has been done to modify and strengthen the science content with no significant outcomes. The teaching and learning of science is not without challenges. Accordingly, teacher leaders in science assist teachers to implement curriculums and teach science better. In the face of the many challenges in science teaching and learning, they assist teachers with expert advice and help them to alter and adapt curriculums as required. More importantly, the concept of teacher leaders in science is a potential source of positive influence to science teaching and learning and improving accountability. We recommend that teacher leaders be part of the instructional leadership configuration that exercise influence in the classroom, revive and sustain communities of practice that are essential for continuous teacher learning and improved learner achievement in science. We further recommend the adoption of school curricula that seek to develop the entirety of STEM literacy.

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