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Research Article:

Leadership in Science Instruction: A Systematic Review of Research

Donnie Adams* and Hamdhiyya
Faculty of Education, Universiti Malaya, 50603 Kuala Lumpur Malaysia

*Corresponding author: drdonnieadams@gmail.com

ABSTRACT

There is growing interest in the role that principals play as school leaders. This systematic review was conducted to identify principal leadership practices that advance science instruction including teaching and learning in schools. In accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, a systematic review was conducted on Web of Science (WOS) and Scopus. This yielded a total of 20 articles. The review of these articles resulted in seven primary themes: facilitating high-quality learning experiences; monitoring the curricular program; creating a safe school environment; distributing leadership to advance science instruction; resources support; recruiting qualified science teachers; and quality teacher professional development programmes. The review has implications in the field of educational leadership and management in revealing how school leaders may contribute to science instruction, including teaching and learning in schools.

Keywords: School leadership, science instruction, systematic review, management practices

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INTRODUCTION

Recent trends have witnessed considerable efforts to improve the quality of science instruction in schools (Lochmiller & Cunningham, 2019; Pringle et al., 2020). The expectation for high student achievement have increased the demand for quality instructional practices in science instruction (Sandholtz, & Ringstaff, 2014; Peacock & Melville, 2019; Yow & Lotter, 2016). However, transforming expectations for quality science instruction into sustained daily practice is difficult and depends largely on school conditions that support teacher and student learning (Whitworth & Chiu, 2015; Yow et al., 2021). Research on educational management and leadership has established that school leaders have a substantial influence on the learning of teachers and students (Leithwood et al., 2020).

Leadership and Science Instruction

Education policymakers around the world have made strengthening school leadership a top priority (Bush, 2020; Hallinger et al., 2018; Liu & Watson, 2020) Scholars believe that the motives and abilities of teachers, as well as the overall atmosphere and environment of schools, are all influenced by effective school leadership, making it crucial towards improved student outcomes (Adams, 2018; Bush, 2020; Lochmiller & Cunningham, 2019). Recent studies have shown that school leadership is second only to classroom teaching as an influence on student learning (Hallinger et al., 2018; Harris et al., 2019; Leithwood et al., 2020).

Effective school leaders use a variety of strategies and management abilities to concentrate their efforts and those of their teaching staff on enhancing science instruction and the learning outcomes of their students (Cherbow et al., 2020; McNeill, Lowenhaupt, & Katsh-Singer, 2018; McNeill, Lowenhaupt, Cherbow, et al., 2022). It also requires exceptional interpersonal skills, as leaders must interact with students, staff, parents, and external groups to get continual input and identify chances for improvement (Adams et al., 2021; Harris, 2020). Scholars in science instruction contend that school leaders' instructional leadership determines a school's capacity to provide high-quality instructional experiences for students, supervision of teachers' instruction and supporting teacher learning (McNeill, Lowenhaupt, Cherbow, et al., 2022; Yow et al., 2021; Yow & Lotter, 2016).

However, school leaders must have a thorough understanding of science instruction to facilitate continual progress and impact classroom teachers' instructional practices (Lochmiller & Cunningham, 2019). Many school leaders do not have expertise in science instruction (Spillane & Hopkins, 2013), have limited understanding of science practices (McNeill, Lowenhaupt, Cherbow, et al., 2022), nor encourage organizational routines that focuses specifically on science teaching and learning (Hayton & Spillane, 2008). The subject presents unique challenges to school leaders, and they find it challenging to supervise and guide teachers (Sandholtz & Ringstaff, 2014).

The recognition of inequities that motivate leadership action in science instruction has prompted the current study to conduct a review on principal leadership practices that advance science instruction including teaching and learning in schools. More specifically, the study addressed a single research question: What does research focused on science instruction suggest school leaders should do to support instructional improvement? In essence, findings from this systematic review study could guide stakeholders and policymakers in the promotion of principal leadership practices for the improvement of science instruction in schools.

METHODOLOGY

This section of the paper outlines a brief discussion of the methodology in this review of the research literature such as identification of sources, data extraction, and data analysis.

Identification of Sources

We conducted our search guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). The PRISMA communicates the procedure we used in identifying sources for our review (see Figure 1). According to Mengist et al. (2020), the development of articles utilising the PRISMA approach involves four phases: identification, screening, eligibility and inclusion.

In the first phase of identification, the search process began with the searching for related and similar keywords based on past research studies. Scopus and Web of Science databases were used to identify relevant studies for this review. One set of main search terms was employed. The key search terms included 'school', 'principal', 'leadership', 'management', 'administrators', 'science instruction'. Search strings on Scopus and Web of Science database were developed after all relevant keywords were determined (Refer to Table 1).

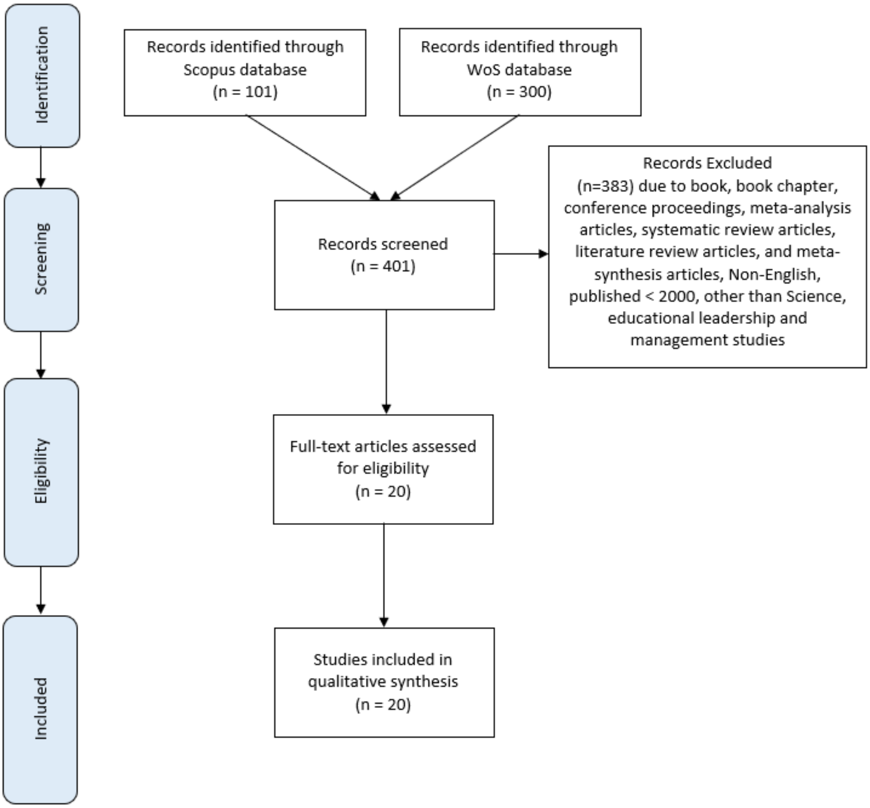

Figure 1. PRISMA flow diagram detailing steps in the identification and screening of sources

Table 1. The search strings

Database	Search string
WoS	TS= ((“principal* lead*” OR “school* lead*” OR “school* head*”) OR (“school* head*”) OR (“school* manage*” OR “school* admin*” OR (“school* manage*”) AND (“science instruction*”))
Scopus	TITLE-ABS-KEY ((“principal* lead*” OR “school* lead*” OR “school* head*”) OR (“school* head*”) OR (“school* manage*” OR “school* admin*” OR (“school* manage*”) AND (“science instruction*”))

Overall, the search yielded a database of 401 articles in the first stage of the systematic review process. In the second stage, 401 articles were screened based on several inclusion and exclusion criteria determined by the researchers. The inclusion criteria to identify the published articles for this review study are as follows:

1. The literature focus is only on journal articles as they are primary sources that offers empirical data. Therefore, publications in the form of book, book chapter, conference proceedings, meta-analysis, systematic review, literature review and meta-synthesis were excluded in the current research.
2. Journal articles must be published in leadership, science instruction, and management practices of principal as the subject area in line with the objective of the review.

In addition, articles published in the field of social science, educational leadership and management studies were selected to increase the possibility of retrieving related articles. Eventually, a total of 383 articles were excluded based on these criteria (see Table 2), leaving 20 articles as the database for analysis.

Table 2. The inclusion and exclusion criteria

Criterion	Eligibility	Exclusion
Literature type	Journal (research articles)	Review journals, book, conference proceeding, thesis, book chapters
Language	English	Non- English
Timeline	Between 2000 and 2022	<2000
Subject area	Science, educational leadership and management	Other than Science, educational leadership and management

Data Extraction

At this stage, the data from all 20 papers were then entered into a Microsoft Excel spreadsheet. Extracted data included the source type, year, author name(s), article title, journal title and methodology (i.e., qualitative, quantitative, mixed method). Data were then coded to enable subsequent quantitative analysis (Gough, 2007). For example, each methodology used in the papers were assigned a code (e.g., quantitative = 1, qualitative =2, mixed methods = 3).

Data Analysis

This study relied primarily on an integrated review method for data interpretation. This approach is used to analyse and synthesise different study designs (qualitative, quantitative and mixed methodologies) by quantitatively or qualitatively transforming qualitative data or quantitative data (Whittemore & Knafl, 2005). All chosen data were subject to qualitative analysis. The analysis was completed in four steps utilizing a descriptive coding strategy commonly used in other forms of qualitative inquiry (Saldaña, 2016). First, we entered all data into a Microsoft Excel spreadsheet as mentioned earlier. Next, we formulated a coding scheme with key leadership practices. For example, we developed codes that specifically addressed: "What specific leadership practices is the most important for science instruction?". Third, we applied these codes to the data in the Microsoft Excel spreadsheet. Finally, we used coding frequencies to develop themes and subthemes.

RESULTS

In this section, the discussion revolves around the findings from the thematic analysis on 20 articles. We discovered the literature stresses principal's leadership practices in creating effective schools that supports science instruction in seven main themes: facilitating high-quality learning experiences; monitoring the curricular program; creating a safe school environment; distributing leadership to advance science instruction; resources support; recruiting qualified science teachers; and quality teacher professional development programmes. We discuss those leadership practices in greater detail in Table 3.

Table 3. The main themes and the sub themes

Authors	FLE	MC	CSE	DL	RS	RQS	TPD
Spillane et al. (2001)					✓	✓	
Knapp & Plecki (2001)					✓		
Stein & Nelson (2003)	✓						
Rigano & Ritchie (2003)					✓		
Larkin et al. (2009)	✓			✓	✓	✓	✓
Shen et al. (2010)	✓			✓		✓	✓
Carrier, et al. (2013)		✓	✓		✓		
Childs et al. (2013)			✓	✓			
Sandholtz & Ringstaff (2014)	✓						
Carrier, et al. (2014)		✓	✓		✓		
Bartolini et al. (2014)			✓	✓	✓		
Akerson et al. (2014)					✓		
Wenner & Settlage (2015)	✓	✓		✓			
Whitworth & Chiu (2015)					✓		
Yow & Lotter (2016)	✓	✓					
Lochmiller (2016)	✓						
Blonder & Mamlok-Naaman (2016)			✓		✓		✓
Kijkuakul (2019)						✓	✓
Pringle et al. (2020)				✓	✓		
Yow et al. (2021)	✓	✓					

Notes: FLE = Facilitating high-quality learning experiences; MC = Monitoring the curricular program; CSE = Creating a safe school environment; DL = Distributing leadership to advance science instruction; RS = Resources support; RQS = Recruiting qualified science teachers; TPD = Quality teacher professional development programmes

Facilitating high-quality learning experiences

Research in science instruction indicates that teacher quality as the most important school-related factor influencing student achievement (Larkin et al., 2009; Shen et al., 2010; Wenner & Settlage, 2015). Scholars in science instruction found that principal's instructional leadership and supervision of teachers' instruction determines a school's capacity to provide high-quality instructional experiences for students (Yow et al., 2021; Yow & Lotter, 2016).

Sandholtz and Ringstaff (2014) study highlights school leaders find it challenging to supervise science instruction. The subject presents unique challenges to both school leaders and teachers alike. The study also found teachers particularly at the elementary level were not confident in their instruction. This highlights the need for high quality supervision and guidance from school leaders. In order to effectively guide their teachers, school leaders need expertise in areas such as subject evaluation and instruction (Stein & Nelson, 2003). School leaders themselves may need support in these areas as their science instruction efficacy can influence what they do to inform, influence or guide teacher's practice (Lochmiller, 2016).

Monitoring the curricular program

School leader's supervisory duties also encompasses creating, reviewing and monitoring the school's curricular program (Yow et al., 2021; Yow & Lotter, 2016). For example, Wenner and Settlage (2015) argued that that the school's curriculum is one of the key levers school leaders may use to affect what teachers teach within the framework of the school's science program. Yow and Lotter (2016) study found that that school leaders have a role in monitoring curriculum and their study provides evidence that principals are well-positioned, owing to their formal position, to promote and lead effective science instruction by making decisions regarding their science instruction's curriculum.

However, studies have indicated that school leader's ability to use the curricular program as a leverage point to improve science instruction is dependable on a system's policy (Carrier,et al., 2013; Carrier, et al., 2014). For instance, few science instruction scholars have voiced their concerns on the influence of policy context that permits school leaders to pay relatively lesser attention to science subjects that do not contribute to the school's accountability measures (Carrier, et al., 2013; Carrier,Thomson, et al., 2014; Sandholtz & Ringstaff, 2014). On the other hand, Sandholtz and Ringstaff (2014) found that school leaders implement science instruction in a way that blends science within literacy. This indicates that school leaders are capable to impact the curricula and the support of the science agenda in their school.

Creating a safe school environment

Science instruction scholars have highlighted school leaders play a crucial role in creating a school environment that supports science teachers in providing high-quality instructional experiences (Bartolini et al., 2014; Blonder & Mamlok-Naaman, 2016; Carrier, et al., 2014;

Childs et al., 2013). These scholars found school environment significantly shapes science teachers' pedagogical and innovative instructional practices. For example, Childs et al. (2013) found school leaders created a trusting and safe environment for science teachers to take risks and experiment with their pedagogy.

Carrier, et al. (2014) discovered that school leaders could directly shape the school environment to provide opportunities for science teacher to collaborate. Bartolini et al. (2014) expressed the need for school leaders to foster "an intellectual, supportive, and trusting relationship" (p. 54) with their science teachers. One of the ways this could be done is by school leaders supporting teachers individually and helping them increase their self-efficacy in science instruction (Blonder & Ma mlok-Naaman, 2016; Carrier, et al., 2013). Blonder and Mamlok-Naaman (2016) shared that school leaders can "foster an environment that encourages teachers to self-reflect on personal classroom practices and the effects of their efforts" (p. 349).

Distributing leadership to advance science instruction

The literature in science instruction provides evidence that leadership that is distributed or shared creates a supportive organisation for learning (Bartolini et al., 2014; Childs et al., 2013). However, we found science instruction scholars merely described how teachers engage in leadership. How school leaders empower teacher leadership within their schools remains relatively unexplored. Most definitions of teacher leadership acknowledge teacher leaders' subject matter competence. Still, scholars suggest that school leaders should let teacher leaders to exert influence outside of their classrooms as part of a school-wide strategy to improve science instruction.

Childs et al. (2013) found school leaders created a school-based environment that enabled teachers to consult with the likes of the head teachers in the science department or other curricular experts. It may be helpful when teacher leaders collaborate with teachers to make pedagogical choices or when they enable teachers to take the lead in classrooms (Pringle et al., 2020). This relieves the teacher leaders of the pressure of modifying instructional procedures and instead allows teachers to cooperate on crucial pedagogical issues (Wenner & Settlage, 2015).

Science teacher–leaders may also function as street-level officials who advocate behaviours leading to high-quality science instruction (Wenner & Settlage, 2015). The best schools are those that have high standards for teaching, learning, foster strong teacher communities, emphasise responsibility and assessment, and promote empowerment for both teachers and students. There is evidence to support the idea that empowering teachers may have a favourable influence on the results for students (Larkin et al., 2009; Shen et al., 2010; Wenner & Settlage, 2015).

Resources support

There have been significant efforts being made over the course of the last decade to improve the quality of science instruction in schools, with scholars recommending that all students should participate in more cognitively challenging science activities (Larkin et al., 2009; Pringle et al., 2020; Rigano & Ritchie, 2003; Spillane et al., 2001; Whitworth & Chiu, 2015). Scholars also stress how scholar leaders could assist science teachers in providing high-quality educational experiences (Knapp & Plecki, 2001). The rising expectations for students' academic performance have resulted in greater demands for innovative instructional practises, which need considerable modifications to the current classroom instruction (Spillane et al., 2001).

However, school leaders often could not provide the necessary resources to support teacher efforts to improve classroom instruction (Bartolini et al., 2014; Pringle et al., 2020). Carrier, et al. (2013) discovered that school leaders overcame this challenge by utilizing subject matter specialists in the school or district and engaging local businesses to acquire donations of materials to support science instructional improvement in the school. There was also suggestion by science instruction scholars for school leaders to provide teachers with adequate collaboration time (Akerson et al., 2014; Carrier, et al., 2014) and school-based instructional support (Blonder & Mamlok-Naaman, 2016; Whitworth & Chiu, 2015) for a successful science instruction (Bartolini et al., 2014).

Recruiting qualified science teachers

The quality of teaching practises in schools often determines the effectiveness of science instruction. Qualified and competent teachers are change agents to enhance the standard of science instruction (Kijkuakul, 2019). The study by Kijkuakul (2019) revealed that it is challenging to make teaching a feasible career option for university students with a science or technology degree. In addition, they asserted that there are no qualified candidates for the vacant science teaching posts. Moreover, the literature indicate that hiring instructors from disciplines other than teacher preparation programmes has both advantages and disadvantages (Shen et al., 2010).

Although teacher education gives a solid foundation in science, yet the school and the classroom are very different environments. Facilitating the career transitions of professionals is indeed a concern for policymakers and school leaders (Larkin et al., 2009). There is a need for innovative, pragmatic programmes that offer assistance to help pre-service teachers in their career transition. Hence, principals' recruitment decisions for quality science instructors should be on attracting the top teaching talents to their school, as opposed to boosting the general application pool (Spillane et al., 2001). Similarly, Shen et al. (2010) acclaims that increased incentives, such as monetary awards, to attract science teachers to specific schools, as well as engaging with the corporate people and local institutions of higher education is vital to employ high quality and competent teachers.

Quality teacher professional development programmes

Science instruction scholars agree that teacher professional development is crucial to the development of high-quality science teachers (Shen et al., 2010). Professional development comprises of trainings aimed to help teachers comprehend how to meet the needs of their students (Kijkuakul, 2019). Traditional approaches to teacher development, such as workshops, outside experts, and time-limited content-based training, should be replaced with new, more effective professional development programmes. (Kijkuakul, 2019). Scholars claim that professional development activities which are persistent, content-based, and classroom-based have a favourable effect on student learning (Larkin et al., 2009; Shen et al., 2010).

Across the science literature, we gathered that school leaders need to ensure adequate professional development programs for science teachers (Blonder & Mamlok-Naaman, 2016). Teacher professional development programs helps science teachers to identify the weaknesses in their instructional techniques (Kijkuakul, 2019). In an effort for school leaders to be successful in providing professional development, they need to take on the role of coaches who instil their teachers with poise in their abilities to teach science and a knowledge of how to improve themselves. In addition, school leaders must dedicate time to engage in collaborative action research, particularly for new science teachers.

DISCUSSION

This systematic review was conducted to identify principal leadership practices that advance science instruction including teaching and learning in schools. Our review of the literature indicates science instruction scholars agree that school leaders play an important role to lead science teachers' effort to deliver high-quality science instruction and support the science agenda in their schools (Bartolini et al., 2014; Blonder & Mamlok-Naaman, 2016; Carrier, et al., 2014; Yow & Lotter 2016). Interestingly, we also gathered school leaders are not the sole actors in this effort.

Rather, school leaders must work alongside teacher leaders in the science department to advance science instruction including teaching and learning in schools (Lochmiller & Cunningham, 2019). The s cience l iterature p osition t eacher l eaders a s k ey p ersonal t o school improvement efforts (Bartolini et al., 2014; Childs et al., 2013; Wenner & Settlage, 2015). They are devoted to enhancing their profession by implementing classroom activities and strategies meant to improve student learning outcomes. Thus, we reiterate that school leaders should support and invite teacher leaders to facilitate and guide the science instruction improvement efforts in their schools.

As for content-specific leadership related to science instruction, we found limited guidance on this aspect within the literature we reviewed. The literature positions school leaders as having the opportunity to influence science by monitoring classroom instruction. However, this may be the most challenging aspect of a school leader's work as scholars suggest it requires an enhanced understanding of the content teachers are covering. Indeed, one of the premises of the current literature is that school leaders must have sufficient knowledge of both content and pedagogy to guide teachers toward improved instructional practices. We gathered that school leaders need expertise in areas such as pedagogical, subject area knowledge, evaluation and instruction (Stein & Nelson, 2003; Yow et al., 2021; Yow & Lotter, 2016).

Nonetheless, science instruction scholars have suggested key leadership practices that support instructional improvement. A school leader's efforts to build a supportive organisation for learning include distributing or sharing leadership among teachers (Bartolini et al., 2014; Wenner & Settlage, 2015). Literature suggests that the efforts of school leaders to establish a learning-supportive workplace are partially a result of shared leadership (Peacock & Melville, 2019). This include co-developing a vision for effective science instruction with teachers; sharing responsibility of teachers' instructional supervision; providing resources to support teacher learning and professional development (Lochmiller & Cunningham, 2019; Pringle et al., 2020; Whitworth & Chiu, 2015).

IMPLICATIONS AND RECOMMENDATIONS

In order to guide teachers effectively, school leaders require pedagogical expertise, and knowledge in subject evaluation and instruction (Stein & Nelson, 2003). This in return will enable the school leaders to assist teachers in their professional growth. The findings of this study indicates that leadership has an influence on science instruction and positioning teacher leaders as key personal to school improvement efforts (Bartolini et al., 2014; Childs et al., 2013; Wenner & Settlage, 2015). However, further research is needed to explore how school leaders empower teacher leadership within their schools.

Furthermore, our review suggests more research is needed to understand how school leaders engage in content-specific leadership behaviours. It is important to explore what leadership actions are most closely associated with improved student learning in science instruction. Future research might examine which leadership practices appear most related to improvements in students' science academic achievement.

CONCLUSION

The recognition of limited systematic review on school leadership in promoting science instruction had prompted the current study to conduct a review of research. However, there are several limitations towards this review of the literature. First, the full literature search yielded a database of 401 English sources. However, this review focused solely on journals articles, thereby reducing the size of the dataset to 20 journal articles in English language. Thus, this review's findings may not represent the full leadership and science instruction literature, especially from review Journals, book, conference proceeding, unpublished master's theses and doctoral dissertations, and book chapters. Nonetheless, this review, provides a sound starting point for identifying future directions for capacity development and developing the school leadership and science instruction knowledge base. Second, despite our best efforts to search all English journal sources on school leadership and science instruction, our search does not claim to capture 100% of the literature. Thus, there might be some journal publications that were missed in the search process. However, it is unlikely that those 'missed journal publications' would radically change the main findings from this review.

In summary, the evidence from this review indicates that enhancing science instruction is crucial to contribute to the technological advancements of the world. In order to bring this change and transformation to science instruction, it is essential for school leaders and teachers to work together by taking initiatives to improve classroom instruction. The evidence from science instruction scholars revealed that school leaders who take initiative in reforming science instruction in schools such as by empowering teachers have a favourable influence on student achievement (Kijkuakul, 2019; Lochmiller & Cunningham, 2019; Wenner & Settlage, 2015).

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