5-2017

Formative Assessment Professional Development for Science Teachers: A Qualitative Meta-Analysis of the Research Literature

Javed Iqbal
University of Tennessee, Knoxville, jiqbal@vols.utk.edu

To the Graduate Council:

I am submitting herewith a thesis written by Javed Iqbal entitled "Formative Assessment Professional Development for Science Teachers: A Qualitative Meta-Analysis of the Research Literature." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Teacher Education.

Mehmet Aydeniz, Major Professor

We have read this thesis and recommend its acceptance:

Stergios Botzakis, Jo Ann Cady

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Formative Assessment Professional Development for Science Teachers:
A Qualitative Meta-Analysis of the Research Literature

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Javed Iqbal
May 2017

DEDICATION

I would like to dedicate this work to my wife (Zaiba) and daughters (Sunaina and Aleena), who missed me for two years because of this study. Despite living 7690 miles away from me, they have always supported me. I would also like to dedicate this work to my parents who have always proven a source of encouragement and inspiration for me not only in my educational life but in my personal life as well.

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to my academic advisor and research supervisor Dr. Mehmet Aydeniz, Associate Professor of Science Education. His scholarly input, constant encouragement, friendly behavior, and immediate and comprehensive feedback made a significant contribution to the successful completion of this study and M.S. program as well. Despite his tight schedule, he always spared time for meetings. I enjoyed working with him, and it proved a paradigm shift and learning experience for me that opened new horizons of learning. Besides my supervisor, I would like to thank my thesis committee, Drs. Jo Ann Cady and Stergios G. Botzakis, for their thoughtful and constructive input to improve the quality of my research.

I am very thankful to the World Learning and United States Agency for International Development (USAID) for financing me with a full-time scholarship to continue this study. The continuous support and assistance of the World Learning team—especially Lisa League, Sarah Levenstam, and Hayley Elszasz—made it possible for me to accomplish this study while coping with homesickness. I am also grateful to the University of Tennessee-Knoxville (UTK) for considering me eligible for this program and guiding me through this two-year academic journey. I am indebted to my organization's education department of Gilgit Baltistan for allowing me to pursue this study.

I appreciate the support of my colleagues Miranda Chen, Norma Torres, Michael Gathman, and Conchita Ramos for their moral support and assistance in proofreading chapters of my thesis. Their support helped me in improving its quality.

I will also take this opportunity to extend gratitude to my family—including my wife, daughters, my parents, my uncle Ashraf, and my brothers and sisters—for their prayers, encouragement, and support which remained a pivotal source of my success during this course.

Last but not least, I cannot ignore the efforts that my teacher Mr. Abdul Jahan; the Director of Education, Mr. Majeed Khan; my brother-in-law Niat Wali; and my colleague Shahzad Hussain, who all helped me obtain a No Objection Certificate (NOC) from my department. Without their support, I would not be able to attend UTK to earn the M.S. degree. It has been the combined effort of all the people that has enabled me to attain this honor. Without them, this study would not have been possible. Thank you all!

ABSTRACT

The major aim of teaching science at the K-12 level is to develop scientific and critical thinking by promoting inquiry skills and fostering a scientific attitude among students. These skills may enable students to solve science-related issues in their daily lives (AAAS, 1990; NRC, 2012). To achieve these objectives, science teachers' professional development in pedagogy and subject matter is indispensable. Particularly, science teachers need to go through professional development programs in the domain of formative assessment so that they will be able to help students to enhance their understanding by assessing their learning through instruction, helping them track their learning through feedback, and providing them with scaffolding to bridge the gap between their learning and curriculum standards. This study presents a qualitative meta-analysis of sixteen research studies regarding formative assessment in different contexts.

Findings of this study reveal that formative assessment has a positive impact on students' academic performance as well as science teachers' professional development. Despite this fact, formative assessment in science is not popular in the circle of researchers and teachers (Sabel, Forbes, & Flynn, 2016). As far as issues are concerned, owing to gaps in science teachers' pre-service training and discrepancies between school-based assessment practices and external exams, the desired outcomes from formative assessment cannot be achieved (Klieger & Bar-Yossef, 2010). To get the desired results from formative assessment, science teachers need to have mastery in their Pedagogical Content Knowledge (PCK) and subject matter. Additionally, formative assessment should be based on close monitoring, feedback, and questioning.

This study suggests that to develop teachers' capacity in formative assessment, sessions on formative assessment need to be conducted regularly. To ensure the implementation of

formative assessment, the informative sessions should be followed by a series of classroom observations and debriefing sessions with science teachers. Besides statewide policy, schools should also formulate an assessment policy. For further investigation of formative assessment, this study suggests the need to conduct a quasi-experimental study investigating the impact of formative assessment. Furthermore, there is also room for conducting a quantitative survey to explore the perceptions and beliefs of teachers regarding formative assessment.

TABLE OF CONTENTS

CHAPTER ONE:

INTRODUCTION TO RESEARCH

Background of the Study

The major aim of teaching science at the K-12 level is to develop scientific and critical thinking, promote inquiry skills, develop reasoning and logic, and foster a scientific attitude among students (Duschl, Schweingruber, & Shouse, 2007; NRC, 2007). These skills are critical for students so that they may be capable of solving science-related issues in their daily lives by drawing connections to science (American Association for Advancement of Science [AAAS], 1990; National Research Council [NRC], 2012). Students can acquire these skills if teachers have the knowledge and skills to facilitate their learning through quality, relevant, and effective science instruction (Kulm, 1994; Deniel & Gumer, 2001).

According to van Aalderen-Smeets and Walma van der Molen (2015), there is a dearth of quality science teachers at the K-12 level in the context of the United States of America (USA). This is because high-performing college and university students opt for fields other than teaching as a career. Specifically, for better financial output, students from upper-class families with outstanding academic records from premier institutes prefer to pursue business, law, and medicine (Anyon, 1981; Monteiro, 2014). Consequently, science is taught mostly by teachers who lack mastery in the subject matter and are equipped with ineffective, teacher-focused, transmission-based, and traditional instructional strategies that have minimal impact on Student Learning Outcomes (Avalos, 2011; Hayes, 1987; Kazempour & Amirshokoohi, 2014).

As a dependable solution for the improvement of quality teaching in science education, science teachers participate in different professional development (PD) programs to equip them with quality instructional strategies for improving their students' learning (Avalos, 2011; Cobern

& Loving, 2002). These sessions are designed to help science teachers develop knowledge and skills needed to conduct inquiry projects, develop scientific thinking, and promote students' conceptual understanding of scientific concepts (Caulfield-Sloan & Ruzicka, 2015; NRC, 2000). Supovitz and Turner (2000) further endorse the idea that "the implicit logic of focusing on professional development as a means of improving students' achievement is that high-quality professional development practices will produce superior teaching in classrooms which will lead to the higher level of students' achievement" (p. 965).

As a result of worldwide reforms over the last decade in science education, science teachers' professional development in the field of K-12 education has gained significant attention and has been emphasized by policy makers, educational administrations, and researchers (Bolshakova & Waldron, 2014; Lomask, Baron, & Greig, 2003). These reforms urged teachers to experience different professional development opportunities for their capacity-building, which increased both the teachers' confidence and the students' achievements in science. However, the impact of these sessions is subject to the quality of the sessions, commitment of the teachers, and availability of a conducive environment at schools (Kazempour & Amirshokoohi, 2014; van Aalderen-Smeets & Walma van der Molen, 2015).

Professional Development on Classroom Assessment

Most of the PD programs are generic and cover various content- and pedagogy-related themes in a limited time. Because they do not focus a particular theme on an intensive basis, science teachers can develop neither an in-depth understanding of a specific teaching domain nor skills to assess students' learning (Bryce, Wilmes, & Bellino, 2016; Deniel & Gumer, 2001). Therefore, National Research Council (NRC) (1996, 2000) & American Association of Advancement of Science (AAAS) (2003) urge all stakeholders of science education to develop and improve assessment-based PD sessions. These sessions will provide benefits in multiple areas: developing the teachers' assessment skills to help students learn through formative assessment, constructing valid and reliable assessment items, properly documenting students' learning, making correct decisions and inferences from assessment information regarding students' learning, and providing meaningful feedback to stimulate students' learning (Aschbacher, 1994; Bansilal & James, 2016).

Formative assessment is part and parcel of the teaching and learning processes since both processes are profoundly shaped by the assessment (Black, 2011; Falk, 2011; Furtak & Araceli Ruiz-Primo, 2001). Information obtained from classroom assessment informs science teachers on the impact of their classroom instruction on student learning. Thus, in response to student performance, teachers reflect on their teaching practices and modify them accordingly, ultimately having a healthy impact on student learning (Black & Wiliam, 1998; Towndrow, Tan, Yung, & Cohen, 2008). Apart from students' academic achievement, formative assessment also reflects the effectiveness of instructional practices and a curriculum's feasibility in a particular context. Thus, formative assessment lies at the heart of the learning process (Cowie & Bell, 1999; Deniel & Gumer, 2001).

Formative assessment has a significant role in science education. Through formative assessment, science teachers uncover their students' ideas, views, and conceptions regarding science. Teachers then use these ideas throughout classroom instruction to motivate students toward the rich understanding of scientific ideas. Rather than solely using summative assessment, science teachers heavily rely on formative assessment since it helps students in learning rather than simply focusing on making decisions about student progress (AAAS, 1999; Deniel & Gumer, 2000; Lyon, 2013; NRC, 2007; NSTA, 2016). Hence, it is necessary to build science teachers' capacity in formative assessment to help students track their own learning progress, enable them to take charge of their learning, adjust instructional skills in accordance with students’ needs, and inform all stakeholders of student academic progress (Araceli Ruiz-Primo & Furtak, 2006; Falk, 2011; Gibbs & Simpson, 2005). The purpose of this study, therefore, is to conduct a meta-analysis of studies related to formative assessment in science.

Rationale for the Study

Reasons for researching the professional development of science teachers in the area of formative assessment arise from my experience of working as a science teacher, teacher educator, and student of assessment during the Master of Science (M.S.) program.

First of all, the logic for conducting this research emanates from my experience of teaching science. In Pakistan, I taught middle school science for six years. Besides simply teaching, I also had to assess student learning through formative as well as summative assessment methods. Through that assessment, I found that students could not meet the standards of the science curriculum, with possible causes including my limited expertise in assessment, student background, and prevailing assessment trends. However, one aspect remained a mystery for me: in most instances, students whose performance was significantly high during the informal assessment could not perform up to a similar mark in summative assessment. This discrepancy raised many questions of whether it happened due to exam phobia, a lack of formative assessment practices, or issues with feedback. Through this study, I want to unfold answers to such emerging questions.

Secondly, apart from teaching, the motivation to pursue this research is also rooted in my background of being a teacher educator. For four years, I worked with teachers to improve their instructional practices by conducting sessions on Pedagogical Content Knowledge (PCK).

Though I covered various topics focusing on different teaching methodologies and other aspects of PCK, at the end of the fourth year, the program evaluation report revealed little improvement in student learning. As a result of participant feedback and self-reflection, I concluded that less attention had been paid to improving the teachers' classroom assessment practices. I had exposed teachers to new teaching strategies, but they continued to use such traditional assessment practices as paper/pencil tests, verbal tests, and multiple-choice tests. I had to re-orient teachers to new formative assessment practices in science—e.g., inquiry projects, portfolios, and two-tier multiple-choice questions—that can improve Student Learning Outcomes SLOs). This study aims to further enrich my understanding of professional development models and the impact of teachers' capacity-building in assessment by improving SLOs.

Finally, during the M.S. program at the University of Tennessee-Knoxville (UTK), I opted for such courses as *Mathematics Assessment* and *Classroom Assessment and Evaluation Techniques* that provided much literature pertaining to formative assessment, measures to improve teachers' assessment practices, and their subsequent impact on student learning outcomes. The course readings created a drive to learn more about the professional development of science teachers in terms of formative assessment and to explore the links of formative assessment on SLOs. Thus, all of these factors motivated this research on science teachers' professional development with respect to their assessment practices.

Prior to this study, various research studies have been conducted on science teachers' professional development in assessment. Towndrow, Tan, Yung, and Cohen (2008); Buck and Trauth-Nare (2009), Araceli Ruiz-Primo and Furtak (2006) and Caulfield-Sloan and Ruzicka (2015) conducted studies on American science teachers' professional development in formative assessment. On the other hand, Aschbacher and Alonzo (2006) and Cowie and Bell

(1999) conducted research regarding the formative assessment model in New Zealand. Despite the existence of these studies, there is an absence of meta-analysis within the realm of science teachers' professional development in formative assessment. Therefore, this study attempts to analyze research work conducted across different contexts on science teachers' professional development in formative assessment to provide readers with a diverse perspective with synthesized findings.

Statement of Problem

Despite various reforms and content-based and pedagogical professional development programs for science teachers, students in K-12 still grapple with the conceptual understanding of scientific ideas, conducting independent inquiry projects, linking science to their daily lives, and developing scientific thinking (Buck & Trauth-Nare, 2009; Greenstein, 2010). Consequently, students fall short of meeting the desired curriculum standard goals, which causes alarm for science education. A plethora of research studies has studied teachers' professional development in science education (Klieger & Bar-Yossef, 2010). However, fewer studies have focused on science teachers' professional development in the realm of formative assessment. This imbalance shows that formative assessment has not received due attention in the field of educational research even though formative assessment practices aid students to maximize their learning outcomes (Bansilal & James, 2016; Gearhart et al., 2006). To improve the quality of formative assessment by linking it with student learning outcomes, educational research must venture into this area, ultimately generating new knowledge of and new dimensions to formative assessment.

In the context of Pakistan, the lack of research and dearth of professional development opportunities for science teachers causes formative assessment to be poorly understood and poorly exercised in the classroom (Iqbal, 1999). Some teachers conduct formative assessments in non-systematic ways, not gathering information about student learning. However, in other cases, they gather information but fail to use it to inform students of their learning (Brookhart, 2008; Martone & Sireci, 2009). Thus, this trend renders formative assessment ineffective, which ultimately affects student learning. To succeed in improving student learning in science education, we as teachers need to adopt formative assessment strategies in such a way that will inform students of their learning progress and enable them to regulate their own learning. Therefore, science teachers' professional development in the domain of formative assessment should be dealt with on a priority basis, for it would expose the teachers to various formative assessment practices, enabling them to replicate those practices to help students achieve the science curriculum standards.

To obtain a synthesized perspective towards and achieve the aforementioned goals of formative assessment, we must analyze the previously conducted yet limited research on science teachers' professional development in the area of formative assessment. Such a review will inform us about the ongoing trends, perspectives, and practices of formative assessment in different contexts. Therefore, this study serves as a meta-analysis of previously conducted research both to gain insight into beneficial practices, impacts, and issues regarding the science teachers' professional development in formative assessment and to analyze the feasibility of those practices in other contexts.

Significance

Multiple research studies have examined science teachers' professional development in assessment in general. This study contributes to the existing body of research by adding knowledge about science teachers' capacity-building in science education with an emphasis on formative assessment. Moreover, findings provide insight to science educators on the professional development of teachers in terms of assessment, thus enabling these teacher educators to conduct contextually relevant and effective sessions on classroom assessment for science teachers. Furthermore, this study enriches science educators' understanding of the philosophical underpinnings and epistemology of PD in science education.

Science teachers also benefit from this study. In addition to expanding their assessment practices, this study will enhance teachers’ understanding of formative assessment with respect to its role in enhancing SLOs. Moreover, they will learn about the challenges that other science teachers face when implementing formative assessment in the classroom. Consequently, they will take measures to cope with these challenges.

This study is conducted under the support of UTK. Therefore, it helps the science education department of UTK in taking informed decisions while designing courses and conducting PD sessions for science teachers regarding assessment in science.

I am lastly pursuing this research through dual roles: as a science teacher and a teacher educator. This study will improve my own understanding regarding the professional development of science teachers in the area of assessment. Ultimately as a science teacher, this study will motivate me to initiate new assessment strategies in the science classroom. As a teacher educator, the findings of this study will provide me knowledge about science teachers’ capacity-building in assessment.

Research Questions

The following research questions will guide the research process:

1) What do research findings in the extant literature say about the impact of formative assessment-oriented PD sessions in science education on students’ learning outcomes?

2) What issues are highlighted by the extant literature regarding the conducting of PD sessions on formative assessment?
3) What common themes can derive from the research on the professional development of science teachers in the field of formative assessment?

Definition of Key Terms

Formative assessment

Formative assessment is a process carried out by teachers and students during instruction to gather information about the progress of student learning in an effort to provide students with useful feedback. This information and feedback can help students by addressing their weaknesses, identifying gaps in their knowledge and learning, and enhancing their understanding of concepts targeted by the curriculum (Kulm, 1994).

Capacity-building

Capacity-building involves enhancing science teachers' mastery of content knowledge and developing their understanding and skills about pedagogy and other domains of teaching and learning through PD sessions (Mervis, 2000).

Pedagogical content knowledge

Pedagogical content knowledge is an integration of teaching skills and subject expertise. It includes the knowledge of subject matter, teaching skills, curriculum, and assessment (Magnusson, Krajcik, & Borko, 1999).

CHAPTER TWO:

RESEARCH METHODOLOGY

Because this study is a qualitative meta-analysis, this section will provide an overview of qualitative research. More specifically, it will focus on the definition of qualitative meta-analysis, its significance, and its philosophical underpinnings. The next section will provide the mechanism, methods, and procedures for searching and selecting relevant articles for analysis. The final section will discuss the criteria for inclusion and exclusion of reviewed articles, along with the limitations associated with this study.

Qualitative Approach

Researchers employ different approaches while embarking on meta-analysis. One approach is a quantitative meta-analysis, in which researchers review quantitative research articles for statistical analysis (Cooper, 2011). Another form is the qualitative meta-research, in which researchers synthesize the findings from relevant qualitative research studies, identify themes, locate gaps, and report patterns that emerged from the identified themes. In addition, Glass, McGaw, and Smith (1981) further divided meta-analysis into two categories: primary meta-analysis and secondary meta-analysis. In the primary meta-analysis, the original data of conducted studies is re-analyzed with better and different analytical strategies; however, in secondary analysis, the findings of previously conducted studies are synthesized and analyzed with a new perspective and dimensions. Concerning the nature of this study, the methodology of choice is qualitative meta-analysis, selected to integrate the findings of 16 studies and answer the new questions emerging from data.

Many reasons lie behind conducting this meta-study within the qualitative paradigm. First, as a researcher, I feel more comfortable with qualitative analysis rather than quantitative or statistical analysis, for I realize that my analytical skills in these areas do not meet the standards of quantitative research. Thus, I decided to conduct this meta-analysis adopting the qualitative approach. Secondly, the purpose of this research is to develop multiple, diverse, integrative, and wider perspectives pertaining to the professional development of science teachers in the domain of formative assessment from previously conducted research work in different contexts. This aim justifies the qualitative approach as an appropriate method since it provides the reader with an "in-depth," "holistic," and broader view of the studied subject (Denzin & Lincoln, 1994; Robson, 2002). Finally, this research aims at "making sense and interpreting"—as well as synthesizing—findings of different research studies from diverse contexts related to science teachers' professional development in formative assessment (Creswell, 2012). Based on these reasons, I opted to conduct this meta-analysis study using a qualitative approach. My goal is ultimately to add knowledge on the existing literature that emerges from this synthesis of research studies.

Qualitative Meta-Analysis

Qualitative meta-analysis is one of the many research approaches that exist within the domain of qualitative research. According to Zimmer (2006), qualitative meta-analysis aims to provide an amalgamated, comprehensive view of different research studies on theory development, higher-level abstraction, and generalizability to make the qualitative findings more accessible for theory and practice. The synthesis of the research is not an ordinary review of previously conducted research studies but rather a systematic and research-based approach for the construction of new knowledge through the interpretive analysis of existing qualitative research findings.

According to Gini and Pozzoli (2013), meta-analysis resembles primary research study. However, in meta-analysis, instead of a human subject, researchers prefer to select different research studies as a unit of analysis, followed by unified results and drawn conclusions from the body of research studies. As a result, meta-analysis provides an integrated review and gist of varied research studies from a particular domain on a particular issue; case for research; or the policy of interest, program, and intervention. This would enable the researcher to investigate and analyze a particular area with different analytical perspectives.

However, Gewurtz et al. (2008) have associated the process of qualitative meta-analysis with a process similar to a literature review, in which researchers use findings from different research studies as data and build new knowledge by assimilating those findings. Additionally, in qualitative meta-analysis, researchers conduct a rigorous secondary qualitative analysis of the primary qualitative findings to uncover the similarities, differences, and patterns amongst different research studies.

The reasons for conducting qualitative meta-analysis are to provide a meaningful and broader description of phenomena and uncover relative patterns and underlying relations from findings of conducted research. This meta-analysis will constitute general principle and cumulative knowledge regarding science teachers' professional development in the area of formative assessment (Timulak, 2009; Wolf, 1986). Schreiber, Crooks, and Stern (1997) state that qualitative meta-analysis is characterized by ''the aggregating a group of studies for the purposes of discovering the essential elements and translating the results into an end product that transforms the original results into a new conceptualization" (p. 314). This characterization implies that the logic of conducting meta-analysis lies in four goals: re-analyzing the findings of different studies from different angles to inform teachers about good teaching practices, helping the educational policymakers formulate research-based policies, figuring out similarities and differences among different studies conducted on similar topics, and providing the crux of different research to analyze one case from various angles (Finfgeld, 2003).

In the past, the utilization of meta-analysis was confined to the fields of medicine and nursing. However, in last two decades, it has been widely employed by researchers in the fields of psychology, sociology, anthropology, political science, and education to disclose best practices in these areas and provide a review of different studies (Barroso & Powel-Cope, 2000; Wolf, 1986; Zhao, 1991). This study aims at conducting a meta-analysis to investigate studies on the professional development of science teachers in the realm of formative assessment. The ultimate goals of this study are to identify exemplary professional development assessment practices for science teachers; synthesize relevant research findings; identify gaps in the literature related to professional development in the field of formative assessment; and offer suggestions for policy, practice, and research. Furthermore, this study also provides knowledge rooted in the findings of different research studies and unfolds both the logic behind good professional development assessment practices and the impact of these practices on student learning and science teachers' professional development. It also adds to literature existing on the feasibility of these practices in other contexts.

Searching and Reviewing Articles

To find relevant articles on science teachers' professional development in assessment, systematic reviews of published research were conducted using such search engines as Elton B. Stephens Co. (EBSCO), the Educational Resource Information Center (ERIC), Web of Science, and Google Scholar. The key search terms used include *science teachers*, *professional development*, *capacity-building*, *professional growth*, and *formative assessment*. The first search yielded 1233 articles relevant to the area of research, with the distribution of articles according to the search engine being the following: ERIC with 591, EBSCO with 442, Web of Science with 123, and Google Scholar with 77. The topics of these articles were then reviewed to filter out irrelevant results, leaving 60 closely relevant articles. Next, the abstracts of these articles were reviewed, and 16 most relevant articles regarding professional development of science teachers in formative assessment were selected for analysis. For the overview of the entire process of meta-analysis, see Figure 1 (Appendix B).

Criteria for Article Selection

Per procedure of the meta-analysis, some criteria were established and used to determine the inclusion and exclusion of articles. The first criterion regarded the publication date of the selected articles. Only those articles that were published during the last two decades were selected for this study, thus including articles published from 1997 to 2017. Additionally, there were a number of studies on this topic available in different journal types. For this study, priority was given to those articles published in peer-reviewed journals. Furthermore, this research is conducted in the domain of assessment in science. Although such disciplines as language studies, mathematics, and social studies possess a plethora of research on assessment, this project selected only those studies that address or investigate assessment within the science discipline. Thus, studies regarding professional development of teachers from other disciplines were exempted from this research. The overview of articles is mentioned in Table 1 (Appendix A).

The focus of both my M.S program at UTK and my research is K-12 education. As such, only those studies that address the professional development of science teachers in K-12 education were analyzed in this research. Thus, articles discussing professional development in science assessment in the context of college, university, or technical education were omitted from this study.

After a thorough reading of each of the 16 articles, the *Findings* sections of each article were re-read, and relevant text was transferred to a separate Word document as data for further analysis. In the next stage, these data were structurally coded by identifying textual excerpts (Lyon, 2013), followed by the extraction of themes from the codes, with each theme aligning with the research questions. Codes were then categorized under each theme. Finally, organizational codes were ascribed to the themes following the APA citation style, using the name of the author and year of publication—e.g., Falk (2011). Themes were categorized under such headings as the impact of professional development, formative assessment-oriented sessions, issues related to PD sessions on formative assessment, and common themes emerged from the analysis. Each theme will be discussed at length in the next section.

CHAPTER THREE:

RESULTS

Introduction

This section presents a detailed analysis of 16 articles reviewed during this study. The analysis was carried out according to the research questions. The first division will share the impact of PD sessions on formative assessment with respect to student learning outcomes and teachers' instructional practices. The next division will analyze those issues faced by teachers when replicating formative assessment practices in the classroom. Finally, the third section will discuss common themes that emerged from the synthesis of articles.

Impact of Formative Assessment-Based Sessions on Student Learning and Teacher Practices

PD sessions on formative assessment practices are beneficial for both teachers and students (Stiggins, 2002; Falk, 2011). This section will discuss the impact of PD formative assessment sessions on both students' academic achievements and science teachers' instructional practices.

Impact of formative assessment on student learning

The ultimate purpose of conducting formative assessment is to help students improve their learning (Yung, 2006; Kulm, 1994). Formative assessment plays a pivotal role in aiding students in their ability to acquire scientific knowledge; reason scientifically; use logic while learning scientific facts, concepts, principals, law, and theories; associate science with their understanding; and communicate scientific knowledge effectively (NRC, 1996).

Araceli Ruiz-Primo and Furtak (2006) worked with science teachers to explore their informal assessment practices. The findings showed that "high-quality informal assessment practices can be linked to increases in students' performance," it illustrates that formative assessment practices directly influence students' academic performance (p. 230). The more we involve students in formative assessment, the richer an understanding they develop; they meet the expectations both of their teachers as well as of the science curriculum (Weeden & Lambert, 2006; NRC, 1996). However, before implementing any formative assessment strategy in the classroom, qualitative aspects must be considered. Quality is defined by the relevancy of formative assessment to curriculum standards, students' level of competency, and the context of the classroom. Moreover, feasibility of feedback also defines the qualitative aspect of any formative assessment.

The review of another study, conducted by Buck and Trauth-Nare (2009), also indicated positive impacts of formative assessment on students. The researchers noted an "increase in students' involvement in the formative assessment process by the completion of the study. In contrast to high-achieving students, other students who had traditionally performed poorly welcomed the formative process, and began to flourish academically" (p.486). Compared to high achievers, low-achieving students need more help and attention from teachers. Because of their lower performance in classroom activities, they are reluctant to participate in classroom activities and unable to meet the standards set by the curriculum. Their low participation in classroom activities may then hinder their ability to develop a substantial understanding of science. These findings show that through formative assessment science teachers can support students in learning science by motivating them to participate in classrooms. Formative assessment will boost their confidence and will motivate them towards learning science (Gearhart et al., 2001; Weeden & Lambert, 2006).

Formative assessment can also promote the culture of collaboration and collegiality among students. Research findings have highlighted that, as a result of involvement in activities based on formative assessment, “students share their ideas with other students to improve upon their responses” (Forbes, Sabel, & Biggers, 2015, p.217). Owing to student engagement in the formative assessment, a sense of cooperative learning develops among students. They assist each other in the learning process by sharing their work. In the classroom, students possess different skills, and they benefit from each other’s competencies as a result of this collaboration. This trend helps students develop not only academically but also socially as they work together to achieve a joint task (Black, 2011).

Furthermore, formative assessment shifts classroom teaching from a teacher-driven approach to a student-centered method, where there is a greater likelihood of full student participation in classroom activities. Thus, the gap between high achievers and low achievers in the classroom and provides opportunities for each student to grow academically (Hänze & Berger, 2007; Ruggieri & Wormeli, 2007). To promote cooperative learning, science teachers should divide students into groups of mixed abilities. Through this grouping strategy, average and below-average learners improve their competencies in science through interaction with high achievers. In a nutshell, cooperative learning works as a catalyst in the academic and social development of the whole class (Araceli Ruiz-Primo & Furtak, 2006). These findings signify formative assessment’s power in stimulating student learning by enabling students to track their learning through self-regulation, improve their performance in the light of feedback, and develop responsibility for their learning. However, formative assessment should be implemented properly, remembering the classroom realities, and should be continued consistently. Rather than being confined to a particular form of formative assessment, science teachers should rely on a variety of strategies and reflect on their formative assessment practices to help students—at both a group and individual level—to develop a sound understanding of science. Such results arise when science teachers are equipped with the skills and knowledge required for the effective implementation of formative assessment, gathered through frequent PD sessions on formative assessment (AAA, 2003; Avalos, 2011).

Impact of formative assessment on science teachers' instructional practices

Apart from student learning, formative assessment strategies play a significant role in science teachers' professional growth by enhancing their instructional practices. In the light of students' responses and information gathered regarding student learning, teachers revisit their pedagogical practices and adopt planned, student-centered instructional practices that expedite student learning by ensuring full student involvement (Cowie & Bell, 1999; Ruggieri & Wormeli, 2007). Findings from Buck et al.'s (2010) intervention-based study revealed that sessions on formative assessment caused:

> a substantial increase in PST [Pre-Service Teachers] level PST of understanding of the purpose of formative assessment….Data from classroom observations and exit cards on days of explicit instruction indicated an increase in the PSTs' ability to distinguish formative assessment from other forms of assessment…. As compared to pretest, in posttest, they found that the majority of pre-service science teachers showed a thorough understanding of formative assessment. They properly elaborate the definition, purpose, and significance of formative assessment in teaching and learning of science. (p. 412)

Science teachers' classroom practices are shaped by their perceptions and beliefs about teaching and learning. Thus, changing their assessment practices without changing their beliefs about classroom assessment will neither be helpful for adopting formative assessment strategies nor be conducive to enhancing students' understanding and required skills (Suurtamm, Koch, & Arden, 2010). Science teachers, like other teachers, possess beliefs about classroom practices. Their practices are deeply rooted in their beliefs and perceptions, which both manifest in their view towards student learning and provide pathways and background to classroom assessment practices (Evans, Luft, & Czerniak, 2014; Pajares, 1992). Enhancing SLOs in science through formative assessment strategies requires a harmony in science teachers' beliefs and practices. While changing science teachers' perceptions of the formative assessment, it is necessary to shift their ideas and conceptions about the accountability aspects of assessment so that the teachers may provide support to students to enhance their learning process (Araceli Ruiz-Primo & Furtak, 2006; Richardson, 1996; Towndrow et al., 2008).

However, improving SLOs requires more than simply expanding teachers' understanding. PD sessions will not serve their actual purpose of supporting students in the learning process by merely developing teachers' understanding (Buck et al., 2010). This argument is echoed in a study in which a research participant viewed PD sessions on formative assessment as "an opportunity to strengthen the way she used assessment evidence to inform her teaching, provide feedback to students, and involve students in tracking their progress" (Gearhart, et al. 2001, p. 245). The impact of the current study is more pragmatic since it directly deals with the practical aspects of classroom assessment, including identifying student progress and giving feedback. Application of formative assessment directly contributes to students' conceptual understanding in science because teachers are helping students to compare their learning to curriculum standards by incorporating teacher feedback. As a result, students will take the ownership of their learning by comparing their current level of science understanding with the curricular goals (Greenstein, 2010; Stiggins, 2002).

Lyon (2013) also worked with PSTs on formative assessment. Findings from his research work reported that:

> the teachers expressed positive attitudes toward providing students with feedback, modifying instruction based on assessment information, and engaging students in self-assessment…. They used the students' own work as a starting point for discussion about target concepts and they asked students to revise their own work after a discussion or re-teaching of the concept. (p. 458)

The excerpt suggests that, besides ameliorating teachers' feedback skills, this intervention also encouraged teachers to engage students in self-assessment practices. Large classes, workload, and time constraints often prevent science teachers from evaluating student learning. However, as a replacement, teachers can engage students' in self-assessment practices. For this purpose, an effective process of self-assessment is necessary. To render the effectiveness of formative assessment through self-assessment, students first need to be clear about the objective of the task: What are teachers expecting from them? What are the guidelines for accomplishing the task? What should be the criteria for evaluating the task (Fwu & Wang, 2012)?

Lastly, student work can be used as a resource to gain information about student learning. After analyzing student work, science teachers will be aware of the strong and weak areas in the students' understanding. The teachers will ultimately focus on weak areas as they design formative assessment strategies. Doing so will help them cater to the learning needs of low achievers, boost their confidence, motivate them to participate in classroom discussions and activities. Ultimately, students develop a sound understanding of science, possessing scientific skills and developed competencies (Ash & Levitt, 2003; Kazempour & Amirshokoohi, 2014).

Findings of all previously cited studies suggest that the engagement of science teachers in PD sessions on formative assessment has a long-lasting and useful impact on their classroom practices. PD sessions not only enhances their content knowledge but also improves their PCK (Towndrow et al., 2011). Apart from this, sessions on formative assessment provide necessary knowledge about formative assessment practices, which help teachers adjust their instruction. Professional development in formative assessment helps science teachers assess students' knowledge in a reliable, valid, and relatively dependable way (Weeden & Lambert, 2006). Thus, it results in upgrading students' learning competencies to sound understandings of concepts, broadly conceptualizing students' understanding, and effecting positive changes in attitude and scientific skills. In order to ensure the effectiveness and sustainability of formative assessment practices, PD sessions must occur periodically on a longitudinal basis rather than one time only (Fwu & Wang, 2012). To ensure the implementation of formative assessment practices in the classroom, there should be a proper mechanism of follow-up, like classroom observations and debriefing sessions. Lastly, science teachers within the school will have to develop a community of learners, where they can discuss and reflect on their formative assessment skills and other classroom practices while benefit from each other's expertise (Lee & Luykx, 2005; Woodland, 2016).

Issues Prevailing in Assessment-Based Professional Development Sessions

Formative assessment contributes to student learning in many ways, like learning scientific concepts, developing scientific attitudes, and enhancing scientific skills (Stiggins, 2002). At the same time, some issues are linked with conducting sessions on formative assessment and its replication in the classroom. If not handled properly, these challenges impede formative assessment's transition into teaching and learning. These issues will be thoroughly elucidated in the following section.

Teachers' lack of understanding of formative assessment

One of the most common issues in formative assessment implementation is that a majority of science teachers lack the required understanding and skills for conducting a formative assessment. Consequently, regarding student achievement, the true impact of formative assessment is not reflected in their classroom (Aschbacher & Alonzo, 2006). Findings from the study of Sabel, Forbes, and Flynn (2016) report that formative assessment "is still rarely a part of elementary science instruction….studies suggest that this may be because teachers do not have a sufficient understanding of formative assessment" (p. 1093). Because teachers poorly understand formative assessment, it is not a common practice in science classrooms, and science teachers are reluctant to apply it while teaching science. Before implementing formative assessment, teachers first need to develop a holistic understanding regarding its functionality, requirements, impact, and role of teacher and students. Then, teachers should master the skills required for the formative assessment. By having command of the theoretical as well as practical aspects of formative assessment, science teachers will be able to implement it effectively. If, however, a teacher lacked any one of these areas, the desired results from formative assessment would not be achieved (Yung, 2006; Bell, 2002; AAAS, 1990).

Discussing the reasons for science teachers' lack of understanding and practice, Forbes, Sabel, & Biggers (2015) argued that formative assessment in the domain of science education has not succeeded in attracting the attention of the researcher. Consequently, few research studies have been conducted in this area; therefore, a dearth of empirical knowledge on formative assessment exists. Moreover, researchers have not investigated it with regard to its feasibility, outcomes, and impact on student understanding. Consequently, science teachers are struggling while searching for research-based knowledge to broaden their conceptualization of formative assessment. To solve this issue, researchers need to conduct large-scale research on formative assessment. In addition, science educators and science teachers can also conduct classroom-based research, like action research, to change classroom assessment practices by introducing a new assessment strategy. Extensive research on formative assessment will not only enhance their understanding of formative assessment strategies but also enable them to apply those strategies proficiently.

By eliciting information about students' prior knowledge, formative assessment is an effective tool for learning students' current state of knowledge. If formative assessment is not prevalent in classrooms, measuring students' level of understanding and eliciting information from them proves difficult. As a result of formative assessment's absence from classrooms, "students' reluctance to express their current level of understanding initially proved to be problematic as we attempted to elucidate their conceptual development" (Buck, Trauth-Nare, & Kaftan, 2010, p. 484). Formative assessment cannot be initiated without having information about students' existing competencies. It is therefore necessary to conduct formative assessment frequently in the classroom. Not only will this assessment motivate all students, especially low achievers, to participate in classroom discussions to share their learning, but it will also help science teachers gather information about student learning and arrange instructional strategies accordingly (Aschbacher,1994; Black & Wiliam, 1998). To increase their understanding of formative assessment, science teachers should be frequently engaged in PD sessions conducted on formative assessment. Doing so will help them to develop a substantive understanding of the theory and practice of formative assessment. In addition to PD sessions, researchers, science educators and science teachers need to investigate formative assessment from different perspectives in different contexts with different approaches, supplying the knowledge to teachers to develop understanding for practicing formative assessment.

Discrepancy between formative assessment practices and external exams

Frequently, teachers experience formative assessment-based sessions but encounter a dilemma once they return to the classroom to implement formative assessment. They find a discrepancy between what they acquire from the PD sessions and what actually happens in the science classroom (Cobern & Loving, 2002). Despite possessing the knowledge and skills, such factors as overcrowded classes, syllabus-coverage issues, workload, and summative schoolwide exams discourage science teachers from applying formative assessment strategies in a productive way. The situation worsens as science teachers take initiatives to prepare students for standardized tests. Often a mismatch exists between formative assessment practices and summative assessment practices, as well as standardized tests (Lomask, Baron, & Greig, 2003).

Klieger and Bar-Yossef (2010) conducted a study in Israel to investigate the reasons behind students' poor performance on science-based standardized tests (e.g., TIMSS, PISA, and GEMS). They found that "these low achievements indicated several weakness foci: in the fields of content, scientific inquiry, integration of skills, and even in the structure and formulation of test items developed by the teachers" (p. 787). Formative assessment is a useful tool for improving students' learning of content measured on standardized exams. Through formative assessment, science teachers diagnose and address students' strengths and flaws in understanding. If effectively and continually implemented, formative assessment can enhance students' performance on summative and standardized tests. For this purpose, aside from formative assessment, science teachers' capacity should also be built regarding the pattern, mechanism, and assessment criteria of standardized and summative tests (Stake, 2010; Klieger & Bar-Yossef, 2010).

Gaps in pre-service training on assessment

Pre-service training plays an important role in the professional development of science teachers. It equips prospective science teachers with skills required for the teaching profession (Buck, Trauth-Nare, & Kaftan, 2010). Sometimes, however, pre-service training does not contribute to a thorough understanding for pre-service teachers (PSTs) in the realm of assessment. As a result, PSTs grapple with assessing student learning when starting their teaching career. Research findings show that “most commonly, the PSTs confused formative assessment with unrelated pedagogical strategies, ongoing summative assessment, standardized and norm-referenced assessment, or all of the above” (Buck & Trauth-Nare, 2009, p. 410). For their professional development, PSTs must develop a broader understanding of formative assessment by being exposed to theory and practice; this exposure would enable them to distinguish between formative assessment and other forms of assessment. Pre-service training needs to be designed in such a way that orients teachers to different models of assessment and equips them with skills required to conduct those models. PD sessions would also make teachers aware of the challenges that other science teachers and students face during these various tests and would enable them to bring coherency among formative, summative, and standardized tests.

Sabel, Forbes, & Zangori (2015) illustrated this same picture of pre-service training: "preservice teachers anticipated students’ ideas and evaluated students’ responses based on their own perceived lack of life science content knowledge. They had difficulty in evaluating evidence of students’ thinking due to their own uncertainty of life science content or how to interpret student responses” (p. 430). Science teachers’ poor command of their subject matter is a major challenge to their professional growth. Sometimes, teachers with average content knowledge participate in pre-service training, but these sessions do not strengthen their grasp of science content. Consequently, they face issues with assessing student learning through formative assessment (Buck, Trauth-Nare, & Kaftan, 2010). All these findings from different research studies show that pre-service training programs are not catering to the assessment needs of prospective science teachers in regards to the subject matter. Science teachers enter the classroom with poor background knowledge of assessment and their subject. Therefore, they cannot assess student learning in a reliable and meaningful way; moreover, they cannot use information regarding student learning in a productive way, making their decisions about student learning unrealistic (Lyon, 2013; Falk, 2011; Escalada & Moeller, 2006). As a dependable solution to this issue, the pre-service training of science teachers needs to focus on both pedagogy and content, empowering the novice science teachers to effectively deliver and assess content through student-centered instruction and effective formative assessment practice.

Common Themes Emerged from the Synthesis of Research Studies

For the successful replication of formative assessment, it must be envisioned a process embodying different subskills rather than as a single entity. Formative assessment can play a pivotal role in improving teaching and learning if the sub-skills are linked to it in accordance with the context and learning needs of students.

Role of PCK in formative assessment

Pedagogical content knowledge (PCK) is part and parcel of teaching and learning. It similarly plays an important role in updating science teachers' assessment skills. Understanding PCK allows science teachers to elicit information about student learning and align formative assessment activities to curriculum objectives (Yung, 2006; Stiggins, 2002). Most of the articles selected for the review highlighted the importance of PCK in designing and conducting formative assessment in science teaching. Falk (2011) asserts,

> PCK is an integral part of teachers' formative assessment practice…. Teachers used knowledge of important learning goals as a means of focusing their interpretation of student responses. Teachers used knowledge of the local curriculum in the process of making connections between multiple aspects of formative assessment. Teachers also used knowledge of instructional strategies as they engaged in formative assessment in multiple ways….Teachers used knowledge of student understanding built through interpretation of the student work in earlier PD sessions to interpret student work in subsequent sessions. (p. 75)

As basic features of PCK, learning goals, curriculum, and assessment are interlinked. The above excerpt shows that these three components are directly involved in the effective functioning of formative assessment and attaining goals. Therefore, science teachers heavily rely on PCK during formative assessment. Through PCK, science teachers set assessment objectives that are parallel to the science curriculum standards and that assess students' competencies in accordance with benchmarks of those standards (Shulman, 1986). Knowledge of instructional strategies helps teachers adjust their instructional strategies in accordance with formative assessment practices and student learning needs. They track student progress and give them productive feedback to reconstruct their understanding (Magnusson et al., 1999). Additionally, teachers elicit students' prior knowledge, infer from student responses, and take further action to address the weaknesses and strengths in those responses. Understanding of PCK, helps science teachers to bridge the gap between student learning and the curriculum standards (Lannin et al., 2013). This intervention indicates that a PCK-oriented capacity-building opportunity contributes greatly to enhancing teachers’ instructional as well as assessment skills, ultimately moving students’ scientific learning forward. The replication of skills also demonstrates that the intervention changes the attitude of the science teachers. Because of this change, they give up the old teaching and assessment practices and lean more towards formative assessment practices.

Jones and Moreland (2005) conducted a study exploring the impact of PCK on science teachers’ classroom assessment practices. They found that PCK-based sessions provide guidelines for initiating formative assessment practices. Having gone through these sessions, science teachers gain conceptual and procedural knowledge that assists them in linking learning to formative assessment activities. These sessions also boost science teachers’ confidence and motivation to translate these practices from PD sessions to the classroom. Overall, PCK significantly impacts science teachers’ formative assessment practices. It provides science teachers with awareness about the learning priorities of their students. Furthermore, PCK-based sessions also hone the feedback skills of teachers, enabling them to provide students with immediate and meaningful descriptive feedback. Most importantly, PCK-based sessions help science teachers blend instructional practices, curriculum, and learning goals so that formative assessment is relevant, effective, and goal-oriented. By identifying learning gaps, they ultimately enables students to improve their conceptual understanding (Gibbs & Simpson, 2005; Magnusson et al., 1999). Because of a rich understanding of PCK, teachers design assessment strategies that cater to student learning needs in regards to curriculum standards. Employing their PCK, science teachers explore their students’ background knowledge and guide students through constructing, deconstructing, and reconstructing their science learning. (Lannin et al., 2013). These practices in turn help improve students’ engagement and possible learning outcomes.

Content knowledge and formative assessment

The review of research studies revealed that teachers' content knowledge also plays a critical role in enhancing science teachers' formative assessment practices. Teachers use their content knowledge as they evaluate students' ideas in science during formative assessment. An analysis of findings further reveals that teachers with strong content knowledge are in a better position to effectively assess students' work (Falk, 2011). Findings of Sabel, Forbes, and Flynn's (2016) study reported that:

> teachers with higher levels of life science content knowledge were able to more effectively evaluate students' ideas than teachers with lower levels of content knowledge. The teachers with higher scores on the content exam discussed both content and student understanding of the concept to a greater extent than teachers in the lower scoring groups. (p.1078)

Content knowledge guides science teachers through making meaning of students' work in terms of their learning achievements and weaknesses (Shepard, 2000). A firm command of content knowledge permits science teachers to make relevant inferences of student learning, determine their lacking areas, and provide remedial support. Furthermore, science teachers with a strong command on content knowledge will be able to develop a good understanding of subject matter, which would help to assess student learning in a valid and reliable way (Falk, 2011). Without having a sound command of content knowledge, identifying students' alternative frameworks and aligning them with scientific concepts proves difficult (Lynch, 1996). Thus, these initiatives will help the teachers improve students' science learning outcomes by deepening their understanding of science (Tamir, 2003). Findings from another study suggested that the relation between formative assessment and content knowledge is reciprocal. At one end, strong content knowledge enables teachers to implement effective formative assessment strategies and make good inference about student learning; at the other end, teachers' engagement in formative assessment practices also strengthens their content knowledge (Sabel, Forbes, Zangori, 2015). This indicates a symbiotic relationship between content knowledge and formative assessment (Klieger & Bar-Yossef, 2010). Teachers' involvement in formative assessment practices in classrooms and during professional development opportunities assists them in building their content knowledge (Sabel, Forbes & Flynn, 2016). Science teachers with an average command of content knowledge would not be able to successfully replicate formative assessment strategies, unable to provide scaffolding to improve student understanding. Thus, the actual objective of formative assessment regarding supporting students would not fail due to science teachers' weak grasp of content knowledge, leading to students' poor performance in summative as well as standardized tests (Escalada & Moeller, 2006). Therefore, PD sessions for teachers should give equal attention to content and PCK.

Role of questioning in formative assessment

Questioning is also an important aspect of formative assessment, especially when centered on oral questions (Shepardson & Britsch, 2001). Science teachers use the questioning technique throughout teaching to gauge students' prior knowledge, their progress, and the effectiveness of the lesson with respect to its objectives (Stiggins, 2002). Research conducted on the role of questioning in formative assessment shows that teachers were identifying students' current level of understanding by employing the questioning strategy. Questioning also helps science teachers to gain insight into asking questions aligned to students' competency levels. Finally, sessions on formative assessment enabled teachers to pay proper attention to students' questions and ask probing questions, in return, to enhance students' critical thinking (Ash &

Levitt, 2003). The questioning benefits both teachers and students. To improve students' questioning skills, teachers first need to ask open-ended questions. Open-ended, process-oriented, and higher-order questions will help students develop an in-depth understanding of science (Fries-Gaither, 2008; Fwu & Wang, 2012). Furthermore, open-ended and process-oriented questions hone the critical thinking, reasoning, and logical skills of students. To promote the culture of asking effective questions, science teachers first will have to develop their own questioning skills. Secondly, they will have to shift their classroom practices from a teachers' centered one-way approach student based discussion approach (Ther & Daviss, 2001).

Caulfield-Sloan and Ruzicka's (2005) study reported that before engaging in PD sessions on formative assessment, science teachers asked mostly close-ended, factual, and lower-order questions from Bloom's (1956) taxonomy. Post-workshop classroom observations showed that the majority of science teachers had shifted their questioning strategy from lower-order to higher-order; close-ended to open-ended; and factual to procedural questioning. Open-ended questions broaden students' understanding while also improving the quality of formative assessment.

To improve students' questioning skills, teachers should develop their questioning skills through capacity-building sessions. In these capacity-building programs, questioning needs to be viewed as a component of formative assessment rather than an isolated entity; and teachers should be encouraged to use higher-order questions from the analysis, synthesis, and evaluation categories of Bloom's (1956) taxonomy. The quality of questions will not be determined by their complexity but by the in-depth and rich understanding that the questions will establish (Frieberg & Driscoll, 2005). Through higher-order questions, teachers will be able to modify students' behavior in a way that develops a scientific attitude within them.

Ruzi-Primo and Furtak’s (2006) study claims that the "teacher whose students had the highest performance on our tests was the teacher who held the most discussions, asked the most concept-eliciting questions, and employed the greatest diversity of strategies that used information she had gained from student understanding" (p. 215). All aforementioned findings make it evident that questioning is an integral part of the formative assessment that contributes to enhancing students’ learning, critical thinking, and engagement in classroom activities. To promote the culture of questioning, teachers should provide ample chances for discussion and welcome student mistakes. Teachers need to include what, when, why, and how questions in their classroom discourse. Lastly, teachers should confine neither themselves nor their students to textbook-oriented questions; instead, teachers will have to look beyond the textbooks and develop high-order questions by themselves (Harlen, 1996).

Feedback in formative assessment

Feedback is the crux of formative assessment because it provides an opportunity to students to gain a greater understanding of their learning progress and encourages them to actively strengthen their learning in the light of science teachers’ feedback (Forbes et al., 2015). An analysis of research highlights that “quality assessment requires… quality tools for gathering evidence of student learning, sound interpretations of the evidence, and quality uses of the information to guide instruction and provide students with useful feedback” (Gearhart et al, p. 241). Formative assessment proves meaningless if not followed by proper, meaningful, constructive, and timely feedback. While giving feedback, teachers will have to carefully consider the information regarding student learning (Deniel & Gumer, 2001). Quality feedback should be provided on time and be comprehensive so that students can get meaning out of it and know where they stand in relation to the learning targets and in what way they can reach those if they are behind (Brookhart, 2008).

Ruiz-Primo and Furtak (2006) further explain the usefulness of feedback, saying that feedback “should assist students in developing the ability to monitor their learning progress, as well as to judge the quality of their own work” (p. 216). Effective feedback would improve Students Learning Outcomes and have a positive impact on their motivation and self-efficacy if students were to incorporate it into their future learning. After giving feedback, science teachers should monitor whether the impact of feedback is reflected in student work. As a result of feedback, students will regulate their learning as independent learners, and teachers would be able to instill the desired academic behavior in students.

Buck and Trauth-Nare (2009) conducted interventions to improve teachers’ feedback practices. Their findings show that science teachers realized the significance of feedback after several cycles of feedback. Feedback enables them to give specific feedback to students instead of such remarks as “you rock” and “good job” (p. 485). Additionally, feedback allows students and teachers to extend their thinking about particular science concepts. The description of feedback is necessary to make any assessment practice useful. First, it should be clear and simple. Students can easily understand what the teacher is expecting from them and what they need to initiate next to enhance their learning. It should be constructive, especially in the case of low achievers; negative feedback discourages them, and they become defensive and, in some cases, abandon yearning for further improvement. It helps students to accomplish not only a particular task but future learning tasks as well. Lastly, it should be specific not general. It should explicitly mention what the current position of the students’ understanding is, where the position should be, and how they can reach the desired position. In addition to informing both teachers and students of the next learning step, this way helps students easily identify their strengths and weaknesses and fulfill teachers' expectations (Aschbacher & Alonzo, 2006).

In summary, when given appropriately, feedback is a valuable tool for expediting student learning. It positively influences their motivation and self-efficacy. Science teachers should attend to the positivity of their remarks, clarity of descriptions, and suggestions for learning improvement. These elements collectively make feedback productive by enriching students' understanding and helping them reach their full potential. Lastly, feedback should be given in a way that not only helps students to accomplish a particular task but also contributes to their future learning (Buck & Trauth-Nare, 2009).

CHAPTER FOUR:

DISCUSSION

This chapter generates a discussion on the findings of this research study. The first section summarizes major topics from the analysis of the literature. The next section elaborates on the study's implications with regard to practice, research, and policy. The final section of this chapter informs readers of the study's potential weaknesses and challenges.

Principles of Formative Assessment

The review of research studies has established that formative assessment is a vital component of the teaching and learning process. The most important outcome of the formative assessment is improvement of SLOs by supporting students throughout instruction (Shepardson, 2001). To achieve this and various other objectives, formative assessment in science must be based on certain guiding principles, highlighted in the literature. However, this section will discuss only those principles that are rooted in this meta-analysis, such as that of the student-centered approach, data orientation, and provision of equal opportunities for all students. These guiding principles will define the working mechanism and the subsequent outcomes of formative assessment.

The student-centered approach is the first and foremost principle of formative assessment. The focus of formative assessment is to improve SLOs by developing students' understanding of, skills in, and attitudes toward science. Doing so does not require students to adjust their learning habits to align with the teachers' instructional strategies; instead, formative assessment emphasizes that science teachers adopt such teaching strategies that can facilitate students in developing a rich understanding of science concepts (Falk, 2011; Stiggins, 2002). In simple terms, formative assessment does not focus on how teachers are instructing but rather stresses how students are learning (Greenstein, 2010). Because of this, science teachers continuously reflect on their teaching methodologies and design them per the students' needs. Thus, they prefer those instructional strategies that facilitate improvement in student learning (Black, 2011; Falk, 2011; NRC, 1996).

Secondly, formative assessment is data-oriented. Science teachers use formal and informal classroom practices to collect data about their students’ ongoing learning. These data informs them about what students are learning, what students need to learn, and what students need as support to reach their full potential. Data also provides an overview regarding the learning of an entire class (Cowie & Bell, 1999). At the same time, these data demands that science teachers align assessment, content, and instruction to achieve curriculum standards; therefore, science teachers consider collecting data during formative assessment. Science teachers should use these collected data to get information about student learning, predict their future progress, and take remedial steps for struggling students (Weeden & Lambert, 2006).

Lastly, formative assessment provides equal learning opportunities for each student. At the same time, it also considers the learning needs and issues of every individual student; for this purpose, in contrast to giving generic and collective feedback to the entire class, formative assessment encourages teachers to provide individual and specific feedback. Furthermore, during formative assessment, students’ competencies and potentials are not compared with each other; rather, students are evaluated in relation to curriculum standards (Greenstein, 2010). Every student in the classroom possesses individual differences, personal backgrounds, and unique learning experiences; thus, in this situation, the desired outcomes of formative assessment cannot be reached by measuring all students with the same yardstick (Lyon, 2013).

Sustainability of Formative Assessment Practices

Enhancing SLOs in science is the essence of formative assessment (Bell, 2002). However, to bring sustainable change in student learning, science teachers should exercise formative assessment practices in their classrooms on a regular basis (Gummer & Shepardson, 2001). Even through continual formative assessment practices, one individual or group of science teachers alone cannot reach the goal of sustainable improvement in students' scientific understanding. It rather must be a collective task of school improvement in which teachers from every discipline participate (Stiggin, 2002).

Marris (1975) suggests that in order to sustain the process of improvement in students' academic achievements, classroom interventions must be based on initiation, implementation, and institutionalization. Science teachers will have to invest energy and time on initiation and implementation because at these opening stages, teachers can encounter resistance from the classroom situation, students, and other stakeholders. However, process will show its impact once formative assessment is adopted as an organizational practice (Wilson, 2013). For the institutionalization phase, formative assessment must be included in the school development plan as an important component, and all teachers will have to commit to facilitating students in the learning process through formative assessment practices. The process of institutionalization will ensure the sustainability in developing a substantial understanding of science among students through reliable formative assessment practices (Yung, 2006). Science teachers should continue to reflect on these practices even after the phase of institutionalization. Through continuous reflection, they may amend the formative assessment strategies according to the progression of students' learning needs and the emerging situation.

Relevancy of Formative Assessment Practices

To improve students' understanding of science, teachers should implement some novel, research-based and student-driven formative assessment practices to gauge student learning. In the pursuit of applying new classroom assessment practices, science teachers ignore their responsibility to student learning. They choose strategies from the literature or good assessment practices from other situations and implement them in the classroom without considering their relevancy in the classroom (Merrifield, 2000). The classroom context plays a central role in any school improvement process. Before doing any intervention related to formative assessment in classrooms, science teachers need to conduct a situational analysis of the classroom context to which the formative assessment practice should align. The analysis will help them figure out the strengths and weaknesses of context with respect to the formative assessment strategy (Sanders, Wright, & Horn, 1997).

According to Beecher and Sweeny (2008), assessment enrichment would provide an opportunity for teachers to assess students' mastery of scientific knowledge within the contextual realities in accordance with the curriculum, rendering the assessment strategy meaningful. While making formative assessment practices relevant, we need to consider different aspects of the classroom context. First, formative assessment needs to be designed with respect to student competency. Often, classroom activities are taken from developed education systems and implanted into classrooms where students' competency levels are not parallel to the standard of the newly installed assessment activities, making the formative assessment unproductive and meaningless (Joyce & Showers, 2002). However, by matching it to the level of the curriculum and student competency, the assessment can be made productive and relevant to classroom context. Apart from student competency, classroom assessment practices can be redesigned with respect to the medium of instruction and tools used for assessing student understanding. With these adjustments in classroom assessment activities, the desired outcomes regarding enhancing students' academic achievements can be achieved.

Framework for Formative Assessment

For the successful implementation and conceptual development of students in science, formative assessment practices need to center on a specific framework, which will define the philosophical underpinnings and specify the operational mechanism for the formative assessment. Additionally, the assessment framework stimulates reflection about the assessment task at the classroom, school, and district levels (Shepardson & Gummer, 2001). Describing the characteristics of the assessment framework, the NRC (1996) asserts that the framework should reflect the best thinking about the knowledge, skills, and competencies needed for a high degree of scientific understanding among all students.

Because of the review of various research work, a framework based on PCK and content knowledge emerged for this study. In this framework, PCK and content knowledge provide foundations for initiating any intervention related to formative assessment. Through content knowledge, science teachers will be able to assess students' scientific understanding and reasoning while PCK will help teachers design relevant tools and mechanisms to formatively assess students' scientific understanding (Falk, 2001). Questioning and feedback will play a supportive role in the execution of formative assessment practices. Through questioning, science teachers will elicit information from students regarding their background knowledge, evaluate their understanding, and involve them in classroom activities (Caulfield-Sloan & Ruzicka, 2005) while feedback will inform students of their learning progress with respect to their achievements and shortcomings. Feedback will also provide guidelines to students for improving their learning according to teacher expectations (Jones & Moreland, 2005). Thus, these four components jointly contribute to enhancing students' learning outcomes, enabling students to track their learning with respect to curriculum standards and develop a sense of responsibility for their own learning (see Figure 2).

This framework also suggests that to reach the desired outcomes from formative assessment practices, science teachers will have to take both content knowledge and PCK side by side, maintaining a balance between the two. Without enough of a command of these two components, science teachers will neither be able to properly execute formative assessment nor bridge the gap between curriculum standards, students, and learning outcomes through formative assessment (Lyon, 2013).

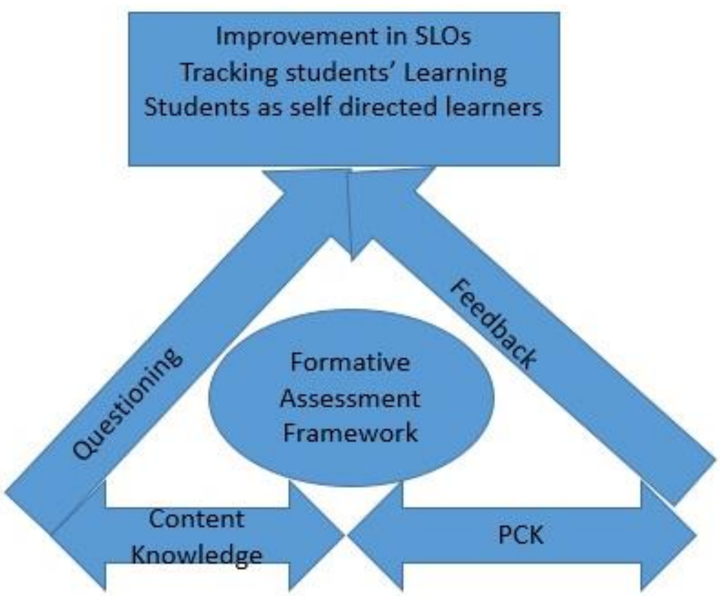


Figure 2: Framework of Formative Assessment

Implications of This Study

This study has many implications that will serve as guiding principles for science teachers, science educator, policymakers, and researchers interested in exploring formative assessment.

Implications for practices

Findings of this study suggest that in most of the cases, science teachers are grappling with understanding formative assessment practices. Owing to lack of understanding, they cannot replicate the practices in an effective and productive manner in their classrooms. Because of this, students cannot develop an in-depth understanding of scientific concepts (Buck, Trauth-Nare, & Kaftan, 2010; Yung, 2006).

To address this alarming situation, schools, district management, and teacher-training institutes need to arrange more PCK-based, formative assessment sessions during pre- and in-service training. These sessions would help the science teachers develop a solid conceptual understanding of formative assessment and hone their classroom assessment skills as well, empowering them to effectively replicate those skills in the science classroom.

Apart from pre-service and in-service training, school administration should also develop a schoolwide mentoring mechanism for ongoing support for science teachers. In this way, experienced and knowledgeable science teachers would assist beginning teachers in building their understanding in the area of formative assessment.

In addition to ongoing support, the school authorities should also come up with a follow-up procedure. In order to ensure the replication of skills and understanding acquired from the professional development sessions, science educators, subject coordinators, and experienced teachers would frequently observe the classroom practices of science teachers. The observations should be followed by debriefing sessions in which the observers inform science teachers of strengths and shortcomings of their teaching while also providing feedback for overcoming those shortcomings.

Implications for policy

This research has some implications for policy as well. First, the findings of this research illustrate that there should be coherence between large-scale assessment reforms and classroom assessment practices. To develop good coordination, this study urges that prior to introducing reforms regarding assessment, the contextual realities of the classroom context need to be considered. This consideration can be done by including science teachers' voices and giving them representation during reform development. This coordination will minimize the paradoxes between large-scale reforms and classroom assessment practices.

Secondly, for the continuation and sustainability of formative assessment practices, school authorities will have to develop an assessment policy at the school level. Formative assessment should be an important component of that assessment policy, encouraging science teachers to implement formative assessment practices in their classrooms. The policy should be formulated in such a way that it would work as a guideline for science teachers to pursue assessment practices in the classroom. Additionally, in this policy, science teachers' ability to apply formative assessment practices in classrooms should be viewed as part of their annual appraisal or performance evaluation. This would further motivate science teachers to continue formative assessment strategies in classrooms on a regular basis. Formative assessment should be included as an important component of the teacher education curriculum. It would help science teachers during pre-service as well as in-service teacher training programs to develop their understanding and skills required for formative assessment.

Finally, findings of this research also indicate that while taking school-based initiatives for formative assessment, there should be an assessment cell or assessment wing, at least at the high school level. This wing would cater to the professional development requirements of science teachers by arranging periodic, school-based professional development sessions for science teachers on formative assessment. At the same time, it would also ensure the provision of resources required to implement formative assessment in the classroom.

Directions for future research

There is a need for conducting further research in the field of formative assessment to explore new dimensions, build more knowledge on the existing literature, and gather more evidence about the potentials of formative assessment and its impact on student learning as well on science teachers' capacity-building.

To explore the impact of formative assessment on student learning, researchers need to conduct a quasi-experimental study with control and experimental groups. Compared to the controlled group, students in the experimental group would be engaged in more formative assessment. The difference in posttest scores of both groups would define the impact of formative assessment.

Research findings have indicated that before changing science teachers' assessment practices, we need to change their perceptions (Araceli Ruiz-Primo & Furtak, 2006; Richardson, 1996). In the same way, before conducting any research interventions regarding science teachers' assessment practices, there is a need for conducting a quantitative survey with a reasonable sample size comprised of many strata, including gender, years of experience, and academic and professional qualifications. Findings of this study will provide a baseline for researchers interested in conducting a study on enhancing the formative assessment practices of science teachers.

As a science educator, I think that besides doing large-scale research studies, we also need to consider taking research initiatives at the school level to develop the understanding and practices of other science teachers. This could be done by conducting action research studies, in which science educators or science teachers would perform the intervention to improve SLOs by building science teachers' capacity in the realm of formative assessment.

Limitations of the study

Qualitative meta-analysis is a useful approach to integrate, review, and analyze prior research work and synthesize findings from diverse perspectives. In spite of these strengths, qualitative meta-analysis has some limitations. Similarly, this study has some issues related to its methodology and procedures.

Research findings indicated that there is a dearth of research work on formative assessment in science education (Forbes, Sabel, & Biggers, 2015). I encountered the same situation, finding only 16 qualitative research studies conducted in the last two decades on formative assessment in science at the K-12 level. Therefore, due to a limited number of studies reviewed for this research and because of its qualitative approach, findings of this study may not be generalized to other contexts (Flick & Flick, 2014).

The purpose of conducting meta-analysis is to review research work from different backgrounds so that it would provide diverse perspectives to the readers. However, in this study, 13 research studies out of 16 were conducted in the context of the U.S.A. Two studies were conducted in Israel and New Zealand while one study was conducted in Singapore and Hong

Kong. Because of the lack of context variability, this study could not provide findings and insights from diverse contexts.

Meta-analysis is an invaluable tool for providing integrative and synthesized research. At the same time, because of its diverse nature in terms of research methods, data collection tools, and data analysis techniques, the selected studies lacked consistency and uniformity, making the comprehensive and in-depth secondary analysis of selected articles difficult (Gini & Pozzoli, 2013).

Subjectivity has also been cited as an issue with qualitative research. Flick and Flick (2014) have indicated that it is impossible for researchers to completely eliminate subjectivity during qualitative studies. However, it can be minimized by avoiding personal, preconceived ideas about the area being researched. In the same way, because of my identification as a science teacher and science educator was preoccupied with my background knowledge of professional development and formative assessment. Thus, my experiential knowledge might have negatively influenced the objectivity of this research.

LIST OF REFERENCES

American Association for the Advancement of Science (AAAS). (1990). Project 2061: Science for all Americans. New York, NY: Oxford University Press.

Anyon, J. (1981). Social class and school knowledge. *Curriculum Inquiry*, *11*(1), 3. doi:10.2307/1179509

Araceli Ruiz-Primo, M., & Furtak, E. M. (2006). Informal formative assessment and scientific inquiry: Exploring teachers’ practices and student learning. *Educational Assessment*, *11*(3), 237–263. doi:10.1207/s15326977ea1103&4_4

Aschbacher, P. R. (1994). Helping educators to develop and use alternative assessments: Barriers and facilitators. *Educational Policy*, *8*, 202–223.

Aschbacher, P. R., & Alonzo, A. (2006). Examining the utility of elementary science notebooks for formative assessment purposes. *Educational Assessment*, *11*(3-4), 179–203. doi:10.1080/10627197.2006.9652989

Ash, D., & Levitt, K. (2003). Working within the zone of proximal development: Formative assessment as professional development. *Journal of Science Teacher Education*, *14*(1), 23–48. doi:10.1023/a:1022999406564

Avalos, B. (2011). Teacher professional development in teaching and teacher education over ten years. *Teaching and Teacher Education*, *27*(1), 10–20. doi:10.1016/j.tate.2010.08.007

Aydeniz, M. (2006). *Understanding the challenges to the implementation of assessment reform in science classrooms: A case study of science teachers’ conceptions and practices of assessment*. (Unpublished doctoral dissertation). Florida State University, Tallahassee, FL.

Bansilal, S., & James, A. (2016). Physical science teachers’ perceptions of an advanced certificate in education. *Problems of Education in the 21st Century*, *70*, 21–33.

Barroso, J., & Powel-Cope, G. M. (2000). Meta-synthesis of qualitative research on living with HIV infection. *Qualitative Health Research, 10,* 340353.

Beecher, M., & Sweeny, S. M. (2008). Closing the achievement gap with curriculum enrichment and differentiation. *Journal of Advanced Academics, 19*(3), 502–503.

Bell, B. (2002). Teacher development in science education. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (1st ed.). (pp. 681–694). Boston, MA: Kluwer Academic Publisher.

Black, P. (2011). *Second International Handbook of Science Education*. New York, NY: Springer-Verlag.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. Assessment in education: *Principles, Policy, and Practice, 5*, 7–74.

Bloom, B. S. (1956). *Taxonomy of educational objectives: The classification of educational goals*. London, UK: Longman Schools Division.

Brookhart, S. M. (2008). *How to give effective feedback to your students*. Alexandria, VA: Association for Supervision and Curriculum Development.

Bryce, N., Wilmes, S. E. D., & Bellino, M. (2016). Inquiry identity and science teacher professional development. *Cultural Studies of Science Education, 11*(2), 235–251. doi:10.1007/s11422-015-9725-1

Buck, G. A., & Trauth-Nare, A. E. (2009). Preparing teachers to make the formative assessment process integral to science teaching and learning. *Journal of Science Teacher Education, 20*(5), 475–494. doi:10.1007/s10972-009-9142-y

Buck, G. A., Trauth-Nare, A., & Kaftan, J. (2010). Making formative assessment discernable to pre-service teachers of science. *Journal of Research in Science Teaching*, *47*(4), 402–421. doi:10.1002/tea.20344

Caulfield-Sloan, M. B., & Ruzicka, M. F. (2015). The effect of teachers' staff development in the use of higher-order questioning strategies on third grade students' rubric science assessment performance. *Planning and Changing*, *36*(3), 157–174.

Cobern, W. W., & Loving, C.C. (2002). Investigation of preservice elementary teachers 'thinking about science. *Journal of Research in Science Teaching, 39*, 1016–1031. doi:10.1002/tea.10052.

Cooper, H. M. (2011). *The SAGE encyclopedia of social science research methods*. Thousand Oaks, CA: Sage Publications, Inc.

Cowie, B., & Bell, B. (1999). A model of formative assessment in science education. *Assessment in Education: Principles, Policy & Practice*, *6*(1), 101–116.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: SAGE Publications.

Deniel, & Gumer (2001). *Assessment in science: A guide to professional development and classroom practice*. Dordrecht, NL: Kluwer Academic Publishers.

Denzin, N. K., & Lincoln, Y. S. (1994). *Handbook of qualitative research*. Thousand Oaks, CA: Sage Publication.

Diamond, B. S., Maerten-Rivera, J., Rohrer, R. E., & Lee, O. (2014). Effectiveness of a curricular and professional development intervention at improving elementary teachers' science content knowledge and student achievement outcomes: Year 1 results. *Journal of Research in Science Teaching, 51,* 635–658. doi: 10.1002/tea.21148.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, D.C.: National Academy Press.

Escalada, L. T., & Moeller, J. K. (2006). The challenges of designing and implementing effective professional development for out-of-field high school physics teachers. *AIP Conference Proceedings*, *1*(818).

Evans, R. H., Luft, J. A., & Czerniak, C. M. (Eds.). (2014). *The role of science teacher beliefs in international classrooms: From teacher actions to student learning*. Rotterdam, NL: Sense Publishers.

Falk, A. (2011). Teachers learning from professional development in elementary science: Reciprocal relations between formative assessment and pedagogical content knowledge. *Science Education*, *96*(2), 265–290. doi:10.1002/sce.20473

Finfgeld, D. L. (2003). Meta-synthesis: The state of the art—so far. *Qualitative Health Research, 13*, 893-904.

Flick, U., & Flick, P. U. (2014). *An introduction to qualitative research*. Los Angeles, CA: SAGE Publications.

Forbes, C. T., Sabel, J. L., & Biggers, M. (2015). Elementary teachers' use of formative assessment to support students' learning about interactions between the hydrosphere and geosphere. *Journal of Geoscience Education*, *63*(3), 210–221. doi:10.5408/14-063.1

Frieberg & Driscoll (2005). *Universal teaching strategies*. Boston, MA: Allyn and Bacon.

Fwu, B., & Wang, H. (2012). Bridging the gap between and beyond school science through collaboration: Promoting science teachers' professional development through diversity and equal partnership. *The Asia-Pacific Education Researcher, 21*(3), 464–473.

Gearhart, M., Nagashima, S., Pfotenhauer, J., Clark, S., Schwab, C., Vendlinski, T., Bernbaum, D. J. (2006). Developing expertise with classroom assessment in K–12 science: Learning to interpret student work. Interim findings from a 2-year study. *Educational Assessment*, *11*(3-4), 237–263. doi:10.1080/10627197.2006.9652990

Gewurtz, R., Stergiou-Kita, M., Shaw, L., Kirsh, B., & Rappolt, S. (2008). Qualitative meta-synthesis: Reflections on the utility and challenges in occupational therapy. *Canadian Journal of Occupational Therapy*, *75*(5), 301–308. doi:10.1177/000841740807500513

Gibbs, G. and Simpson, C. (2005). Conditions under which assessment supports students' learning. *Learning and Teaching in Higher Education*, 12(1), 135–188.

Gini, G., & Pozzoli, T. (2013). Bullied children and psychosomatic problems: A Meta-analysis. *PEDIATRICS*, *132*(4), 720–729. doi:10.1542/peds.2013-0614

Glass, G.V., McGaw, B., & Smith, M. L. (1981). *Meta-analysis in social research*. Thousand Oaks, CA: SAGE Publication.

Hänze, M., & Berger, R. (2007). Cooperative learning, motivational effects, and student characteristics: An experimental study comparing cooperative learning and direct instruction in 12th grade physics classes. *Learning and Instruction*, *17*(1), 29–41.

Harlen, W. (1988). *The teaching of science.* London, UK: David Fulton Publishers.

Hayes, L. D. (1987). *The crisis of education in Pakistan*. Lahore, PK: Vanguard.

Iqbal, M. Z. (1994). *Science Education in Pakistan: Retrospect and prospect.* Bulletin of Education and research XVI, (1-2).

Jones, A., & Moreland, J. (2005). The importance of pedagogical content knowledge in assessment for learning practices: a case-study of a whole-school approach. *Curriculum Journal*,*16*(2), 193-206. doi:10.1080/09585170500136044

Joyce, B. R., & Showers, B. (2002). *Student achievement through staff development*. Alexandria, VA: Association for Supervision and Curriculum Development

Kazempour, M., & Amirshokoohi, A. (2014). Transitioning to inquiry-based teaching: Exploring science teachers' professional development experiences. *International Journal of Environmental & Science Education*, *9,* 285-309.

Klieger, A., & Bar-Yossef, N. (2010). Professional development of science teachers as a reflection of large-scale assessment. *International Journal of Science and Mathematics Education*, *9*(4), 771–791. doi:10.1007/s10763-010-9216-5

Kulm, G. (1994). *Mathematics assessment: What works in the classroom* (1st ed.). San Francisco, CA: Jossey-Bass Inc.

Lannin, J. K., Webb, M., Chval, K., Arbaugh, F., Hicks, S., Taylor, C., & Bruton, R. (2013). The development of beginning mathematics teacher pedagogical content knowledge. *Journal of Mathematics Teacher Education*, *16*(6), 403–426. doi:10.1007/s10857-013-9244-5

Lee, O., & Luykx, A. (2005). Dilemmas in scaling up innovations in elementary science instruction with nonmainstream students. *American Educational Research Journal*, *42*(3), 411–438. doi:10.3102/00028312042003411

Lynch, P. P. (1996). Students' alternative frameworks for the nature of matter: A cross-cultural study of linguistic and cultural interpretations. *International Journal of Science Education*, *18*(6), 743–752. doi:10.1080/0950069960180607

Lyon, E. G. (2013). Learning to assess science in linguistically diverse classrooms: Tracking growth in secondary science preservice teachers' assessment expertise. *Science Education*, *97*(3), 442–467. doi:10.1002/sce.21059

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95–132). Washington, DC: National Academy Press.

Marris, P. (1975). *Loss and change.* New York, NY: Anchor/Doubleday.

Martone, A., & Sireci, S. G. (2009). Evaluating alignment between curriculum, assessment, and instruction. *Review of Educational Research, 79*(4), 1332–1361. doi:10.3102/0034654309341375

Mervis, J. (2000). Teacher training: How to produce better math and science teachers. *Science*, *289*(5484), 1454–1455. doi:10.1126/science.289.5484.1454

Monteiro, A. (2014). *The teaching profession: Present and future*. Lisbon, PT: Springer.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and national science education standards.* Washington, DC: National Academy Press.

National Research Council. (2007). *Systems for state science assessment*. Washington, DC: National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

NSTA (2016). Big and Small Seeds Linking Formative Assessment Probes to the Scientific Practices. National Science Teacher Association. Retrieved on March 13, 2017 from http://static.nsta.org/files/sc1609_20.pdf.

Otero, V., Pollock, S., McCray, R., & Finkelstein, N. (2006). Who is responsible for preparing science teachers? *Science*, *313*(5786), 445–446. doi:10.1126/science.1129648

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307. doi:10.2307/1170741

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102–119). New York, NY: Macmillan.

Robson, C. (1998). *Real world research*. Oxford, UK: Blackwell Publishers.

Ruggieri, C. A., & Wormeli, R. (2007). Authentic assessment in action. *English Journal*, *96*(4), 111. doi:10.2307/30047178.

Sabel, J. L., Forbes, C. T., & Flynn, L. (2016). Elementary teachers' use of content knowledge to evaluate students' thinking in the life sciences. *International Journal of Science Education*, *38*(7), 1077–1099. doi:10.1080/09500693.2016.1183179

Sabel, J. L., Forbes, C. T., & Zangori, L. (2015). Promoting prospective elementary teachers' learning to use formative assessment for life science instruction. *Journal of Science Teacher Education*, *26*(4), 419–445. doi:10.1007/s10972-015-9431-6

Sanders, W. L., Wright, S. P., & Horn, S. P. (1997). Teacher and classroom context effects on student achievement: Implications for teacher evaluation. *Journal of Personnel Evaluation in Education*, *11*(1), 57–67. doi:10.1023/a:1007999204543

Schreiber, R., Crooks, D., & Stern, P. N. (1997). Qualitative meta-analysis. In J. M. Morse (Ed.), *Completing a qualitative project: Details and dialogue* (pp. 311326). Thousand Oaks, CA: Sage.

Shepardson, D. P., & Britsch, S. J. (2001). *Assessment in science: A guide to professional development and classroom practice*. Dordrecht, NL: Kluwer Academic Publishers.

Shepardson, D. P. & Gummer, E.S. (2001). A framework for thinking about and planning classroom assessment in science. In D. P. Shepardson & S. J. Britsch (Eds.), *Assessment in science* (pp. 83–92). Dordrecht, NL: Kluwer Academic Publisher.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4 – 14.

Stake, R. (2010). Some comments on assessment in U.S. Education. *Education Policy Analysis Archives, 6*, 14. doi:10.14507/epaa.v 6n14.1998

Stiggins, R. J. (2002). Assessment Crisis: The Absence of Assessment for Learning. *Phi Delta Kappan,83*(10), 758-765. doi:10.1177/003172170208301010

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963–980.

Suurtamm, C., Koch, M., & Arden, A. (2010). Teachers' assessment practices in mathematics: Classrooms in the context of reform. *Assessment in Education: Principles, Policy & Practice*, *17*(4), 399–417. doi.org/10.1080/0969594x.2010.497469

Timulak, L. (2009). Meta-analysis of qualitative studies: A tool for reviewing qualitative research findings in psychotherapy. *Psychotherapy Research*, *19*(4-5), 591–600. doi:10.1080/10503300802477989

Thier, H. D. & Daviss, B.(2001). *Developing inquiry-based science materials: A guide for educators.* New York, NY: Teacher College Press.

Towndrow, P. A., Tan, A.-L., Yung, B. H. W., & Cohen, L. (2008). Science teachers' professional development and changes in science practical assessment practices: What are the issues? *Research in Science Education, 40*(2), 117–132. doi:10.1007/s11165-008-9103-z

van Aalderen-Smeets, S. I., & Walma van der Molen, J. H. (2015). Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of Research in Science Teaching, 52*(5), 710–734. doi:10.1002/tea.21218

Weeden, P., & Lambert, D. (2006). *Geography inside the black box: Assessment for learning in the geography classroom*. London, UK: nferNelso.

Wilson, S. M. (2013). Professional development for science teachers. *Science, 340*(6130), 310–313. doi:10.1126/science.1230725

Wolf, F. M. (1986). Meta-analysis: Quantitative methods for research synthesis. *Contemporary Sociology, 16*(6), 911. doi:10.2307/2071646

Woodland, R. (2016). Evaluating PK-12 professional learning communities: An improvement science perspective. *American Journal of Evaluation, 37*(4), 505-521. http://dx.doi.org/10.1177/1098214016634203

Yung, B. H. W. (2006). *Assessment reform in science fairness and fear*. Dordrecht, NL: Springer.

Zhao, S. (1991). Metatheory, meta-method, meta-data-analysis: What, why, and how? *Sociological Perspectives, 34,* 377-390.

Zimmer, L. (2006). Qualitative meta-synthesis: A question of dialoguing with texts. *Journal of Advanced Nursing*, *53*(3), 311–318. doi:10.1111/j.1365-2648.2006.03721.x

APPENDICES

APPENDIX A: LIST OF SELECTED ARTICLES

Table 1. Overview of Articles Selected for the Meta-Analysis

S#	Title	Author/ Year	Context	Participants	Methodology	Methods
1	Examining the utility of elementary science notebooks for formative assessment purposes	Aschbacher & Alonzo (2006)	USA	8 protocol teachers	Mixed method	Note books, pre- and post-test scores, and rubric of performance assessment
2	Working with the zone of proximal development: Formative assessment as professional development.	Ash & Levitt (2003)	USA	2 teachers	Case study	Ethnographic field notes and interviews
3	Making formative assessment discernable to pre-service teachers of science	Buck, Trauth-Nare, & Kaftan (2010)	USA	Total 30 PSTs (5 male and 25 females)	Action research	Questionnaires, transcripts, course documents, interviews, and field notes
4	Preparing teachers to make the formative assessment process integral to science teaching and learning	Buck & Trauth-Nare (2009)	USA	4 secondary science teachers	Cooperative inquiry	Transcripts, lesson plans, interviews, classroom observations, and student work

Table 1. Continued.

S#	Title	Author/ Year	Context	Participants	Methodology	Methods
5	The effect of teachers' staff development in the use of higher order questioning strategies on third grade students rubric science assessment performance	Caulfield-Sloan & Ruzicka (2005)	USA	120 third grade students and 27 teachers	Quasi-experimental mixed method approach	NA
6	A model of formative assessment in science education	Cowie & Bell (1999)	New Zealand	10 teachers	Qualitative study	Participant observation interviews, surveys, and audiotapes
7	Teachers learning from professional development in elementary science: Reciprocal relations between formative assessment and pedagogical content knowledge	Falk (2011)	Southwestern United States	11 fourth-grade teachers from a large urban school	Action research	Video recordings of PD sessions, teacher, posters, transparencies, and student work samples

Table 1. Continued.

S#	Title	Author/ Year	Context	Participants	Methodology	Methods
8	Elementary teachers' use of formative assessment to support students' learning about interactions between the hydrosphere and geosphere	Forbes, Sabel, & Biggers (2015)	USA	26 third- through fifth-grade teachers from 13 schools (21 female and 5 males)	Mixed method	Interviews and survey
9	Developing expertise with classroom assessment in K–12 science: Learning to interpret student work. Interim findings from a 2-year study	Gearhart et al. (2006)	USA	3 middle school science teachers	Case studies	Interviews
10	Professional development of science teachers as a reflection of large-scale assessment	Klieger & Yossef (2010)	Israel	55 teachers	Mixed method (quantitative and qualitative)	Interviews, questionnaires, and content analysis

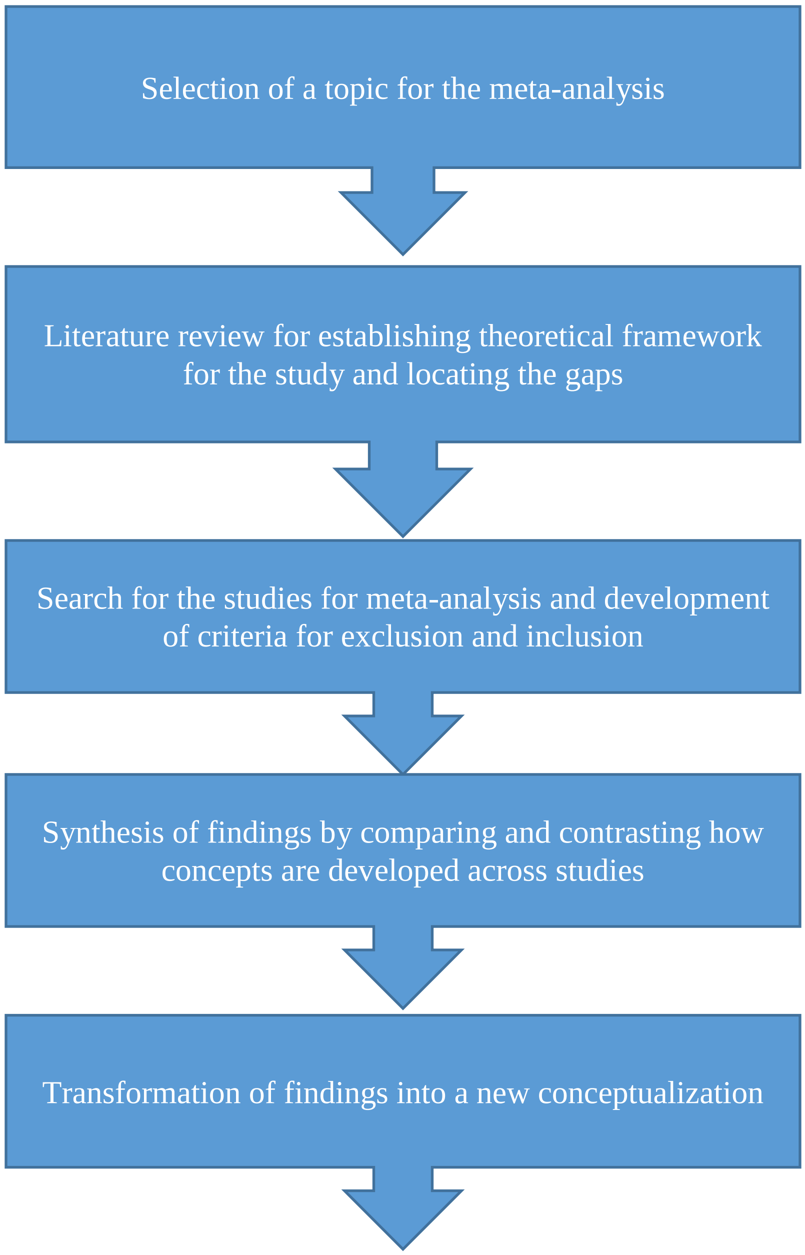
Table 1. Continued.

S#	Title	Author/ Year	Context	Participants	Methodology	Methods
11	Learning to assess science in linguistically diverse classrooms: Tracking growth in secondary science preservice teachers' assessment expertise	Lyon (2013)	USA	26 third- fifth-grade teachers recruited from 13 schools (21 female and 5 males)	Mixed method	Interviews and surveys
12	Assessing understanding of the energy concept in different science disciplines	Park & Liu (2015)	USA	6 middle school science teachers	Case studies	Interviews and video recordings
13	Science teachers' professional development and changes in science practical assessment practices: What are the issues?	Phillp, Tan, Yung, & Cohen (2008)	Hong Kong and Singapore	2 teachers from each context	Case studies	Interviews and documents
14	Informal formative assessment and scientific inquiry: Exploring teachers' practices and student learning	Ruiz-Primo & Furtak (2006)	Hawaii at Manoa	4 middle-school teachers and students	Mixed method	Video recordings of classroom teaching

Table 1. Continued.

S#	Title	Author/ Year	Context	Participants	Methodology	Methods
15	Promoting prospective elementary teachers' learning to use formative assessment for life science instruction	Sabel, Forbes, & Zangori (2015)	USA	49 (4 males and 45 females) teachers	Embedded mixed methods	Assessments, artifacts, interviews, and pre- and post-tests
16	Elementary teachers' use of content knowledge to evaluate students' thinking in the life sciences	Sabel, Forbes, & Flynn (2016)	USA	32 teachers of 12 schools from 4 school districts	Sequential explanatory mixed-methods research design	Students' artifacts and instructional logs

APPENDIX B: QUALITATIVE META-ANALYSIS STEPS



Adopted with modifications (Gewurtz, Stergiou-Kita, Shaw, Kirsh, & Rappolt, 2008)

Figure 1. Steps Involved in Qualitative Meta-Analysis

VITA

Javed Iqbal is hailing from Gilgit-Baltistan, Pakistan. Having completed his undergraduate degree in pre-medical in 2001, he decided to join teaching profession as a primary school teacher. Since then, he has been teaching English and Science at primary and secondary levels. Apart from his teaching experience, he also worked as teacher educator from 2011 to 2014. In this position, he worked on the capacity-building of teachers from the government sector in Pakistan. He has already earned an M.Ed. degree in teacher education from a private university in Pakistan, and at the University of Tennessee Knoxville (UTK), he pursued his M.S. in teacher education.