Chapter # 32

SCIENCE TEACHERS' PERCEPTIONS AND PRACTICES ON USING MOBILE-BASED INFORMAL FORMATIVE ASSESSMENT FOR INQUIRY-BASED TEACHING IN SOUTH AFRICAN SCIENCE CLASSROOMS.

Noluthando Mdlalose[1], Umesh Ramnarain[1], & Mafor Penn[2]
[1]*Science and Technology Education, University of Johannesburg, South Africa*
[2]*Childhood Education, University of Johannesburg, South Africa*

ABSTRACT
The proliferation of mobile technologies in different contexts contributes to the rapid and extensive implementation of mobile-based teaching and learning practices across the globe. Effective implementation of mobile-based informal formative assessment practices in science classrooms could yield to scientifically literate learners who are able to communicate, work collaboratively to construct knowledge and think critically. Data was collected from four purposively selected science teachers around Gauteng province, through questionnaire, classroom observations and stimulated-recall discussions. The findings from the questionnaire indicated that all four participating science teachers still enact formative assessment following the traditional and teacher-dominated approach. Numerous challenges such as insufficient classroom time, inadequate resources and unstable Wi-Fi connection hinders teachers from frequently practicing inquiry-based instructional strategies and technology-enhanced formative assessment. Although these four science teachers have experienced numerous challenges, they have pointed out numerous benefits of implementing mobile-based formative assessment for inquiry-based learning. Benefits such as enhanced learner engagement, knowledge construction, participation, motivation, and comprehension of scientific concepts during the learning process were reported. However, certain changes such as flexible curriculum, adequate teaching and learning time and adequate and relevant teacher professional development must be implemented to ensure successful mobile technology-enhanced formative assessment for inquiry-based learning practices.

Keywords: formative assessment, informal formative assessment, inquiry-based teaching, mobile technologies.

1. INTRODUCTION

The shift from traditional teacher-dominant teaching approaches towards inquiry-based teaching approaches has led to a critical consideration of technological tools that have great potential to effectively support formative assessment practices in an inquiry-based science classroom. Trending technologies such as mobile technologies are developed and rapidly integrated into educational contexts to offer adequate support to teachers for the effective enactment of formative assessment practices (Woolf, 2010). The 21st-century learners are regarded as a technology-savvy generation that is eager to experiment and enjoy learning and assessments through educational applications such as Kahoot! Socrative and Quizizz on their mobile devices (Anamalai & Yatim, 2019).

Research reveals that game-based formative assessment tools such as Socrative and Kahoot! have a positive impact on the learners' learning experiences, enhancing learners' motivation and active engagement toward science learning (Ismail & Mohammad, 2017). It is accordingly important for science teachers to adopt and use mobile technologies to support effective informal formative assessment practices for inquiry-based teaching. Although mobile-based formative assessment is still an emerging area in the mobile learning research context, mobile technologies have great potential in facilitating formative assessment practices in an inquiry-based classroom (Nikou & Economides, 2018). Formative assessment is an important component in the teaching and learning process which supports learners in acquiring skills, knowledge, and expertise that will help them to be critical and competent learners in the 21st-century era (Nikou & Economides, 2018).

Currently, the skills that are in demand in the 21st-century era include communication, critical thinking and creativity, and collaboration. There are numerous benefits associated with the effective use of mobile technologies for formative assessment practices. To point out a few benefits, ***firstly***, mobile technologies enable easier administration of formative assessment activities (Bacca-Acosta & Avila-Garzon, 2021). ***Secondly***, formative assessment conducted through mobile technologies has the potential of enhancing learners' motivation and achieve the stipulated learning goals (Nikou & Economides, 2018). ***Thirdly***, mobile technologies can further support a wide variety of assessment practices such as formative assessment, informal formative assessment, and game-based assessment (Sung, Chang, & Liu, 2016). ***Fourthly***, the effective use of mobile technologies can help teachers to successfully assess their pedagogical practices as well as the learners' competencies related to 21st-century knowledge and skills such as critical thinking, collaboration, creativity, communication, and problem-solving (Nikou & Economides, 2018). ***Fifthly***, mobile technologies can be used to capture learners' performance and analyze the captured data to inform the next teaching and learning steps while providing appropriate support to learners according to their needs and level of conceptual understanding based on their performance (Sung et al., 2016).

Empirical research (Oyelere, Suhonen, Shonola, & Joy, 2016) has reported that mobile devices play a vital role in learners' academic achievement, providing adequate support to foster meaningful teaching and learning experiences and improve engagement with the learning material, collaboration, enjoyment, and interest, promoting continuous interactions and can also facilitate innovative pedagogical strategies that will equip learners with higher-order thinking skills. Despite the numerous affordances associated with mobile-based formative assessment practices in the 21st-century era, science teachers are experiencing numerous challenges that hinder the successful enactment of informal formative assessment using mobile technologies. Lack of appropriate teaching and learning resources, adequate technical and management support, teachers' adequate knowledge and experience, and teachers' positive attitudes and beliefs towards mobile-based formative assessment are the main challenges that hinder teachers from implementing mobile-based formative assessment (Nikou & Economides, 2018). It is noticeable that teachers receive arguably little or no guidance to select and effectively implement mobile technologies for formative assessment when following an inquiry-based pedagogical approach. Grob, Holmeier, & Labudde (2017) argue that teachers' lack of formative assessment literacy has been reported and professional development is suggested as an approach to developing teachers' formative assessment literacy.

1.1. Conceptualizing Informal Formative Assessment

Ruiz-Primo (2011) describes informal formative assessment as a practice that allows the teacher and learners to collect evidence of learners' understanding by using various assessment opportunities. In any classroom, the informal formative assessment can take place between the teacher and learner and learner-to-learner interaction, depending on the purpose of the assessment. Therefore, the informal formative assessment does not require naturally predictable events that occur in any classroom but requires ongoing small-scale, frequent learning opportunities that teachers will use to collect, analyze, and interpret learners' performance and conceptual understanding toward the stipulated learning goal (Ruiz-Primo, 2011). Thorough planning, structuring of assessment questions, and timing are critical aspects required to ensure that teachers implement informal formative assessment effectively in real-time every day (Ruiz-Primo, 2011). This means that when teachers are practicing informal formative assessment, they need to be aware that informal formative assessment is consistent with the purpose of sound educational assessment which goes beyond conventional assessment. Informal formative assessment requires teachers to make decisions "on the fly" and allow them to reflect in action and use learners' responses to direct the next teaching and learning step.

The informal formative assessment constitutes social nature as one of the fundamental mechanisms by which learning occurs even beyond the classroom and various contexts. As a result, learning activities such as classroom conversations can foster the social nature of informal formative assessment in the classroom. Ruiz-Primo (2011) argues that informal formative assessment should create opportunities for 'evaluating, modifying and re-thinking the learning opportunities intended to enable learners to achieve their learning goals" (p.16). In the 21st century era, there is an increasing expectation that teachers will use technological tools, including mobile technology to teach and assess learners' learning. Accordingly, there have been developments in what should be expected of 21st-century learners in today's world, which is characterized by 21st-century demands. These learners are expected to acquire 21st-century skills including critical thinking, problem-solving, communication, creativity, collaboration, and innovation (Luckin, Clark, Avramides, Hunter, & Oliver, 2017). The adoption and negotiation of these skills suggest a need to review the ways in which students' learning is assessed, which implies that teachers must adopt and improve their pedagogical and formative assessment strategies. Assessment strategies such as mobile-based assessment can be employed in a classroom in such a way that learners acquire the in-demand 21st-century skills. The focus of this chapter is on investigating the benefits and challenges that in-service science teachers experience when enacting mobile-based formative assessment for inquiry-based learning in a South African classroom.

2. BACKGROUND

We live in a world where teachers are constantly challenged to reflect, modify, and change their pedagogical strategies to fit with current trends and demands. Innovative pedagogical strategies are necessary in a 21st-century classroom where learners will be equipped with adequate knowledge and skills to be competent and meet the demands anywhere in the world, in the present and future. There are numerous factors that play a significant role in the teaching and learning process, such as the school structure, organization, policies, and management but what happens in the classroom between the teacher and the learners is very crucial. This includes the assessment process which is an integral part of teaching and learning. Therefore, it is important to understand how mobile technology can be used to administer formative assessments that will enhance learners' conceptual understanding, communication, collaboration, and critical thinking, and ensure that all learners attain and exceed the intended curriculum intended aims. In South Africa, the White Paper on e-Education, further emphasizes that the thoughtful and successful integration of technological devices can enhance the learners' motivation and productivity, improve the quality of the teaching and learning processes, and promote high-order thinking skills such as critical and creative thinking, scientific reasoning and problem-solving (Department of Education White Paper on e-Education, 2004).

Mobile learning is perceived as a process of learning mediated by technological handheld devices such as smartphones, tablets, Personal Digital Assistants (PDAs), and e-book readers to enhance and support the teaching and learning process (Kukulska-Hulme, Lee, & Norris, 2017). Mobile learning is perceived as a form of learning that occurs through social and content interactions in multiple contexts using personal handheld electronic devices. Based on these perceptions, mobile learning mainly emphasizes how learning is tethered from various contexts and how learners learn the subject matter artifacts using mobile technologies (Crompton, Burke, & Gregory, 2017).

These mobile technological devices have been repeatedly claimed to offer flexibility and assistance in enhancing the learners' motivation, interest, and autonomy while supporting learners in interacting and collaborating with their peers, as well as increasing the learners' engagement and cognitive growth during the learning process (Khaddage, Müller, & Flintoff, 2016). Empirical research has reported several benefits of the successful use of mobile technologies in classrooms. Crompton et al. (2017) point out that mobile technologies can be used to afford learners contextualized and personalized learning experiences and provide both learners and teachers with affordances to interact anytime from various locations. Learning concepts through mobile technology-enhanced approaches could afford learners the opportunities to reflect deeply, acquire adequate communication and collaboration skills, and promote social and constructivist learning. Mobile learning technologies have been reported to be a powerful tool that can be employed in a classroom to enhance pedagogical practices while ensuring that the needs of the 21st digital native learners' need are met to ensure meaningful and self-regulated learning.

Furthermore, Cerratto Pargman, Nouri, and Milrad (2018) stipulate that those mobile technologies foster different types of mobile activities including a mix of instructions, assessing, and providing constructive formative assessment feedback to the learners. There is a growing emphasis on ensuring that teaching and learning activities promote creative, constructive, and interactive learning environments by using current trending technologies, such as mobile technologies. Ozdamli (2012) posits that learning activities facilitated through mobile technologies such as mobile cell phones are underpinned by learning theories such as the constructivist learning theory. Based on Piaget's (1967) cognitive constructivism and Vygotsky's (1978) social constructivism which together shape the nature of inquiry-based instruction, several instructional models of inquiry have been developed. Constructivism is a paradigm that assumes that knowledge is subjective, contextual, and inherently partial and has become particularly prominent in science education through the focus on Inquiry (Minner, Levy, & Century, 2010). Accordingly, Dias et al. (2008) assert that the constructivist learning theory is the most significant learning theory for describing learning that is facilitated by mobile technologies. Suarez, Specht, Prinsen, Kalz, and Ternier (2018) point out that the integration of mobile technology in an inquiry-based context affords opportunities for new guidance, interactivity in technology-supported inquiry-learning activities, and participation in classroom conversations and knowledge construction. According to Elliot, Ngugi, and Malgwi (2018), technological tools can be used by teachers to successfully administer formative assessment in both formal and informal approaches. Internationally, K-12 public schools have introduced the Bring Your Own Device (BYOD), which encourages teachers to implement technology as a formative assessment tool. Research conducted by Charlesworth (2012) reported that using technology in a classroom presents several benefits, including increased learner engagement, offering a simple and quick way of providing feedback to both the learners and the teacher, which will further help the teacher to have a clear understanding of the learners' learning progress and comprehension.

Laurillard (2007) highlights the importance of the dialogue interactions between the teacher and the learners, which is mediated through educational technology platforms in order to improve the learners' understanding of particular phenomena. The integration of technology in the formative assessment practices will further allow learners to revisit the questions anytime they need while enabling both learners and teachers to monitor progress and gather feedback on the entire teaching and learning process.

Empirical research has shown that the use of formative assessment can foster meaningful learning for learners and support the development of inquiry competencies in learners in science classrooms (Black & Wiliam, 2005; Hume & Coll, 2010).

Formative assessment is regarded as an "assessment for learning" and a critical process that involves interpreting the evidence of learner performance, which is then used to inform the next teaching and learning step (Grob et al., 2017). Additionally, formative assessment is typically practiced in classrooms with the aim of testing the abilities, skills, and knowledge that learners acquired in order to achieve the desired learning outcomes (Alotaibi, 2019). Research (Alotaibi, 2019; Young & Jackman, 2014) posits that although teachers have positive attitudes towards formative assessment practices, they are reluctant and less confident to effectively implement formative assessment in their classrooms. This situation is due to various reasons including time constraints, excessive workload, large class sizes, teacher anxiety, ambiguous guidelines for effectively enacting formative assessment practices, and a rigid curriculum, which is summative in nature and forces teachers to teach for summative assessment purposes (Alotaibi, 2019).

The lack of adequate understanding of formative assessment on the part of teachers has been observed as one of the determinant factors of either successful or unsuccessful implementation of formative assessment practices in classrooms (Vandeyar & Killen, 2007). Consequently, teachers who have an adequate understanding of formative assessment practices will effectively employ it daily in their classrooms; whereas teachers who have an inadequate understanding of formative assessment practices, will not employ this practice in their daily teaching practices. The National Policy on Assessment and Qualifications for Schools is aimed at guiding teachers to effectively apply formative assessment and use it to identify the learners' learning difficulties, which are then addressed early before the summative assessments. Black and Wiliam (2005) posit that teachers can experience formative assessment as an effective and beneficial practice only if the teachers have adequate understanding to accept and use it to enhance learners' conceptual understandings and skills during the learning process in a classroom.

The rationale for this exploratory qualitative case study is to obtain a more in-depth understanding of the significant role played by the use of mobile technologies by teachers when enacting formative assessments for inquiry-based teaching of science subjects. Given the above-mentioned reasons behind the South African science teachers' inability to enact mobile technology-enhanced formative assessment practices in inquiry-based teaching, the current study is relevant because it seeks to:

- Identify the challenges that impede LS and PS teachers from enacting mobile technology-enhanced formative assessment practices in inquiry-based teaching.
- Suggest the empowerment evaluation approach as a professional development strategy that will help in overcoming intrinsic and extrinsic factors affecting the effective implementation of mobile technology-enhanced formative assessment.

3. RESEARCH QUESTIONS, AIMS, OBJECTIVES, METHODOLOGY, AND DESIGN

3.1. Research Question, Aim, and Objectives

Despite global empirical research (Sung et al., 2016; Grob et al., 2017) that has reported the significant role of implementing mobile-learning technologies in an inquiry-based pedagogy, the teachers' experiences, and challenges in the use of mobile-based formative assessment, not many studies in science education have reported on the teachers' experienced benefits and constraints with the use of mobile-based formative assessment in a South African context. Thus, for this study, the overall aim was to investigate South African science teachers' experienced benefits and constraints with the use of mobile-based formative assessment for inquiry-based teaching. The following research question was posed to drive the inquiry.

What are science teachers' experienced benefits and constraints with the use of mobile-based formative assessment for inquiry-based teaching?

In answering the posed research question, we purposively and conveniently selected four science teachers from around the Gauteng province schools, which presumably had the resources for enacting mobile-based formative assessment and inquiry-based teaching to participate in this study. The objectives included to;

- *investigate science teachers' experienced benefits with the use of mobile-based formative assessment for inquiry-based teaching.*
- *explore science teachers' experienced constraints in the use of mobile-based formative assessment for inquiry-based teaching.*

3.2. Theoretical Framework

The constructivist learning theory proposed by Vygotsky (1978) and Piaget (1967) was adopted as suitable to theoretically guide this study. Constructivism has two categories, namely social constructivism (Vygotsky, 1978) and cognitive constructivism (Piaget, 1967) which both shape the nature of inquiry-based pedagogy and provide explanations on how individual learners adapt and refine knowledge through active and collaborative participation. Aligning to constructivism learning theory, empirical research Ozdamli (2012) pointed out that the constructivist learning theory is the most significant learning theory for describing, guiding, and underpinning learning facilitated through mobile technologies.

3.3. Research Methodology

Creswell and Creswell (2017) define qualitative research methodology as an approach that gives the researcher room to be descriptive and consider social phenomena. Taking into consideration this definition, the qualitative research methodology was adopted and deemed suitable for gathering data that will help us answer the research question of this study. A case study design was adopted as it a design that allowed the researcher to follow participant science teachers over an extended period.

3.4. Data collection and analysis

Participants of this study included four science teachers' pseudonyms as T_A, T_B, $T_{C,}$ and T_D from three different South African schools in Gauteng province. Three teachers had 5 – 6 years experience of teaching science subjects such as Life Sciences and Physical Sciences, and the fourth teacher had a three-year experience of teaching Life Sciences. Data was collected in three stages namely, Stage 1 – open-ended questionnaires: Stage

2- classroom observations, and Stage 3- stimulated-recall discussions. Open-ended questionnaire data collected in stage 1 was collected with the aim of identifying participants' perceptions on enacting mobile-based formative assessment for inquiry-based teaching. In Stage 2 of data collection, classroom observations were video-recorded with the aim of understanding the actual practices of the participating science teachers in terms of how they enact mobile-based formative assessment in inquiry-based teaching within a natural setting of their classrooms. The video-recorded lessons were approximately 45 – 60 minutes long per lesson. All open-ended questionnaire responses from stage 1 and video-recorded stage 2 data were transcribed and analyzed using thematic and deductive coding, in order to identify the correlation and differences between the science teachers' perceptions and actual pedagogical practices of mobile-based formative assessment for inquiry-based teaching. Thereafter, the findings from the first two stages guided the formulation and administration of the questions for the stimulated-recall discussions for stage 3 of the data collection.

4. RESULTS AND FUTURE RESEARCH DIRECTIONS

Regarding formative assessment, findings from the open-ended questionnaire analyses revealed that the science teachers do practice formative assessment in a traditional, teacher-dominated approach, with the aim of testing learners' understanding of the content, identifying any knowledge gaps, and helping learners to prepare for summative assessment. Some of the formative assessment activities they used included homework activities, class shirt quiz, question-and-answer, and spot tests. However, these forms of formative assessment practices do not provide teachers with opportunities to provide instant feedback and continuously probe learners' responses by asking follow-up questions during the teaching and learning process. Formative assessment activities such as classwork and homework activities require teachers to have a couple of days of marking and give feedback to the learners, by that time learners have even forgotten what they were learning, this somehow affects the continuous sequence between one lesson to the next. As a result, it becomes a challenge for teachers to use learners' performance and use it to inform the next teaching and learning step. Furthermore, the findings indicated that these science teachers seldom implement mobile technologies to enact formative assessments. During the stimulated-recall discussions, they indicated that there are numerous hindrances to the successful enactment of mobile-based formative assessment for inquiry-based learning. The identified hindrances include insufficient classroom time, limited knowledge on various forms of formative assessment, and inadequate knowledge and skills on the use of mobile applications such as Kahoot! and Socrative and mobile technology integration to effectively enact formative assessment every day throughout the lesson. Only two out of four participant teachers have experienced and know how to use mobile-based formative assessment platforms such as Socrative and Kahoot!, while the other two have no experience and knowledge of such platforms for conducting the formative assessment.

Following the nature of this study, the participating science teachers were provided with guidance on how to conduct formative assessments using platforms such as Kahoot! On mobile technologies. Thereafter, they were given an opportunity to implement Kahoot! for mobile-based formative assessment. During the observations of the lessons, it was revealed that inadequate knowledge and skills have an impact on how teachers enact mobile-based formative assessment for inquiry. As it was clearly visible that these teachers do not understand the key significance of using formative assessment, instead to them it is just another approach for engaging learners and keeping them active during the lesson. Overall, it was observed that all four participating science teachers could not complete their lessons within the stipulated lesson time, they could not analyze, interpret and use learners' performances from the Kahoot! and Socrative to inform the next teaching and learning step. Wi-Fi connectivity issues were observed and the coherent teaching and learning process was affected.

Accordingly, these findings were fully explained by the participating science teachers during the stimulated-recall discussions, where they indicated that school context and certain socio-economic factors contribute to how teaching and learning take place. For instance, in two schools - learners do not normally bring mobile devices to school for learning purposes and some learners cannot afford such devices, which hinders' full learner participation during mobile technology-enhanced teaching and learning. Secondly, the time allocated per lesson, which is ranging between 30 to 60 minutes is insufficient for teachers to effectively engage learners, and ensure meaningful and constructive learning, as a result, exploration, elaboration, and even assessment time are very limited, and thereafter, teachers tend to bend towards traditional, teacher-dominant teaching. Thirdly, there were noticeable differences between the teachers' use of game-based formative assessment, as one out of four used Socrative while the other three used Kahoot! platform. Only 2 out of 4 participating teachers managed to use learners' responses to stimulate classroom discussions and ask follow-up questions with the aim of identifying knowledge gaps and enhancing learners understanding before moving to the next quiz questions. Whereas the other two teachers only administered the Kahoot! and Socrative at the end of the lesson with little to no interpretation and use of learners' responses to inform the next teaching and learning step.

The findings from this study reveal that although science teachers recognize the importance of incorporating mobile technologies and have acquired basic knowledge and skills to effectively enact mobile-based formative assessment for inquiry-based teaching, their mobile-based formative assessment practices still require extensive guidance and development. These findings concur with research findings such as (Cochrane, 2014; Sung et al., 2016; Grob et al., 2017) that attest that mobile technologies can be successfully implemented and be more effective with pedagogies such as inquiry-based teaching and formative assessment, however, teachers are experiencing difficulties in implementing mobile technologies for inquiry-based teaching and formative assessment due to lack of adequate knowledge and skills, inadequate teaching and learning resources, large class sizes, insufficient teaching time. South African curriculum structure does not give teachers opportunities to be flexible and teach according to their classroom context as they must rush to complete the prescribed syllabus content on time, as a result, the use of mobile-based formative assessment for inquiry-based teaching is not possible as this pedagogical approach requires time for preparing, administering, and discussing learners' input during the learning process.

Based on the above-presented results, there is still a need for meaningful development of in-service teachers in equipping them with adequate knowledge and skills to enact 21st-century pedagogy like the mobile-based formative assessment. Based on these findings, we recommend that the science education fraternity including, Department of Education authorities, researchers, and teacher educators provide intervention programs for in-service teachers on the effective enactment of mobile-based formative assessment for inquiry-based teaching. Studies of this nature could help inform higher institutions and teacher-training programs about the gaps and the type of guidance and support required to equip teachers with adequate knowledge and skills to effectively enact mobile-based formative assessment for inquiry-based teaching.

5. CONCLUSION

Based on the literature reviewed in this study, it can be concluded that the enactment of mobile-based formative assessment can improve learners' interest and engagement in science classrooms. However, the effective enactment of mobile technology-enhanced formative assessment is still a challenge for South African science teachers. Taking into consideration the 21st-century technology-savvy learners we have in science classrooms; the traditional use of formative assessment practices and non-inquiry-based pedagogies are no longer relevant and effective for teaching and learning. Even though the challenges that in-service teachers experience when enacting mobile technology-enhanced formative assessment in inquiry-based science classrooms still need to be addressed, the data studied suggest that the benefit of this pedagogical practice and EE professional development approach are great. This conclusively confirms that the EE professional development approach to providing adequate support and training to in-service science teachers needs to be seriously considered with the aim of improving the teaching and learning of science concepts through innovative pedagogical strategies.

REFERENCES

Alotaibi, K. A. (2019). Teachers' Perceptions on Factors Influence Adoption of Formative Assessment. *Journal of Education and Learning*, *8*(1), 74. https://doi.org/10.5539/jel.v8n1p74

Anamalai, T. R., & Yatim, M. H. (2019). A comparative study of formative assessment tools. *Journal of Information System and Technology Management*, *4*(14), 41–71. https://doi.org/10.35631/jistm.414006

Bacca-Acosta, J., & Avila-Garzon, C. (2020). Student engagement with mobile-based assessment systems: A survival analysis. *Journal of Computer Assisted Learning*, *37*(1), 158–171. https://doi.org/10.1111/jcal.12475

Black, P., & Wiliam, D. (2005). The Formative Purpose: Assessment Must First Promote Learning. *Yearbook of the National Society for the Study of Education*, *103*(2), 20–50. https://doi.org/10.1111/j.1744-7984.2004.tb00047.x

Cerratto Pargman, T., Nouri, J., & Milrad, M. (2017). Taking an instrumental genesis lens: New insights into collaborative mobile learning. *British Journal of Educational Technology*, *49*(2), 219–234. https://doi.org/10.1111/bjet.12585

Charlesworth, M. (2012). Promoting the use of classroom response systems, Learning with mobile technologies, handheld devices, and smartphones: Innovative methods. *Huddersfield, UK: The University of Huddersfield.*

Cochrane, T. D. (2014). Critical success factors for transforming pedagogy with mobile Web 2.0. *British Journal of Educational Technology*, *45*(1), 65–82. https://doi.org/10.1111/j.1467-8535.2012.01384.x

Creswell, J.W., & Creswell, J.D. (2017). *Research design: qualitative, quantitative, & mixed methods approaches (5th ed.).* Thousand Oaks, CA: Sage

Crompton, H., Burke, D., & Gregory, K. H. (2017). The use of mobile learning in PK-12 education: A systematic review. *Computers & Education*, *110*(110), 51–63. https://doi.org/10.1016/j.compedu.2017.03.013

Dias, A., Carvalho, J., Keegan, D., Kismihok, G., Mileva, N., Nix, J., & Rekkedal, T. (2008). *An introduction to mobile learning. Work Package.*

Department of Education. (2004). White paper on e-education. *Government Gazette*, (236734).

Elliot, E. A., Ngugi, B., & Malgwi, C. A. (2018a). Mitigating microfinance marketing channels inefficiencies with customerization of mobile technology. *International Marketing Review*, *35*(4), 619–636. https://doi.org/10.1108/imr-11-2015-0256

Grob, R., Holmeier, M., & Labudde, P. (2017). Formative Assessment to Support Students' Competences in Inquiry-Based Science Education. *Interdisciplinary Journal of Problem-Based Learning*, *11*(2). https://doi.org/10.7771/1541-5015.1673

Hume, A., & Coll, R. (2010). Authentic student inquiry: the mismatch between the intended curriculum and the student-experienced curriculum. *Research in Science & Technological Education*, *28*(1), 43–62. https://doi.org/10.1080/02635140903513565

Ismail, M. A.-A., & Mohammad, J. A.-M. (2017). Kahoot: A Promising Tool for Formative Assessment in Medical Education. *Education in Medicine Journal*, *9*(2), 19–26. https://doi.org/10.21315/eimj2017.9.2.2

Khaddage, F., Müller, W., & Flintoff, K. (2016). Advancing mobile learning in formal and informal settings via mobile app technology: Where to from here, and how? *Educational Technology and Society*, *19*(3), 16-26.

Kukulska-Hulme, A., Lee, H., & Norris, L. (2017). Mobile Learning Revolution: Implications for Language Pedagogy. *The Handbook of Technology and Second Language Teaching and Learning* (C. A. Chapelle & S. Sauro, Eds.; pp. 217–233). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118914069

Laurillard, D. (2007). Pedagogical forms of mobile learning: framing research questions. In N. Pachler (Ed.). Mobile learning: Towards a research agenda (pp. 153-175). London: W1.E Centre.

Luckin, R., Clark, W., Avramides, K., Hunter, J., & Oliver, M. (2017). Using Teacher Inquiry to Support Technology-Enhanced Formative Assessment: A Review of the Literature to Inform a New Method. *Interactive Learning Environments*, *25*(1), 85-97. https://doi.org/10.1080/10494820.2015.1121152

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction-what is it and does it matter? Results from a research synthesis years 1982 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474-496.

Nikou, S. A., & Economides, A. A. (2018). Mobile-based assessment: A literature review of publications in major referred journals from 2009 to 2018. *Computers & Education, 125,* 101-119. https://doi.org/10.1016/j.compedu.2018.06.006

Oyelere, S. S., Suhonen, J., Shonola, S. A., & Joy, M. S. (2016, October). Discovering students mobile learning experiences in higher education in Nigeria. In *2016 IEEE Frontiers in Education Conference (FIE)* (pp. 1-7).

Ozdamli, F. (2012). Pedagogical framework of m-learning. *Procedia-Social and Behavioral Sciences*, *31*, 927-931. https://doi.org/10.1016/j.sbspro.2011.12.171

Piaget, J. (1967). The mental development of the child. *Six psychological studies*, 3-73.

Ruiz-Primo, M. A. (2011). Informal formative assessment: The role of instructional dialogues in assessing students' learning. *Studies in Educational Evaluation*, *37*(1), 15–24. https://doi.org/10.1016/j.stueduc.2011.04.003. ISSN:0191-491X

Suarez, A., Specht, M., Prinsen, F., Kalz, M., & Ternier, S. (2018). A review of the types of mobile activities in mobile inquiry-based learning. *Computers & Education*, *118*, 38-55. https://doi.org/10.1016/j.compedu.2017.11.004

Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education*, *94*, 252-275. https://doi.org/10.1016/j.compedu.2015.11.008

Vandeyar, S., & Killen, R. (2007). Educators' conceptions and practice of classroom assessments in post-apartheid South Africa. *South African Journal of Education*, *27*(1), 101-115.

Vygotsky, L. S. (1978). *Mind in society: The development of Higher Mental Processes,* (edited by Cole, M., et. al). Harvard University Press, Cambridge, Massachusetts.

Woolf, B.P. (Ed.) (2010). *A Roadmap for education technology*. Washington, DC: The National Science Foundation. Retrieved from http://cra.org/ccc/wp-content/uploads/sites/2/2015/08/GROE-Roadmap-for-Education-Technology-Final-Report.pdf

Young, J. E., & Jackman, M. G. A. (2014). Formative assessment in the Grenadian lower secondary school: teachers' perceptions, attitudes and practices. *Assessment in Education: Principles, Policy & Practice*, *21*(4), 398-411. https://doi.org/10.1080/0969594x.2014.919248

AUTHOR(S) INFORMATION

Full name: Noluthando Mdlalose
Institutional affiliation: University of Johannesburg
Institutional address: P.O Box 524, Auckland Park, 2006. South Africa
Short biographical sketch: Noluthando's interests lie in developing both in-service and pre-service teachers who are flexible, innovative, and enthusiastic about teaching Natural Sciences, Life Sciences, and Physical Sciences effectively in the 21st -century era. With regard to developing in-service and pre-service teachers, she views her teaching and research from various innovative perspectives in the educational context. These include the use of technology to enhance the teaching and learning experience in Science classrooms, the use of technology to enhance formative assessment practices in a science classroom, and the effective implementation of inquiry-based approaches. So far, she has completed her Master's qualification where she focused on in-service teachers, with the aim of professionally developing them through the Empowerment Evaluation approach. The key focus of the study was to examine the role and effect of the empowerment evaluation approach in supporting and guiding in-service teachers when they enact mobile technology-enhanced formative assessment practices for inquiry-based learning.

Full name: Umesh Ramnarain
Institutional affiliation: University of Johannesburg
Institutional address: P.O Box 524, Auckland Park, 2006. South Africa
Short biographical sketch: Professor Umesh Ramnarain's research focus is mainly inquiry-based learning. His research is on inquiry teaching and learning, and its uptake in South African classrooms characterized by diversity and complexity in terms of intrinsic and extrinsic or environmental factors. The knowledge base he has built has important implications at both the national and international levels, especially in terms of inquiry teaching in underprivileged schools.

Full name: Mafor Penn
Institutional affiliation: University of Johannesburg
Institutional address: Chris Hani, Soweto, Johannesburg, 1809. South Africa
Short biographical sketch: Mafor Penn currently works as a science lecturer at the Department of Childhood Education, University of Johannesburg. She holds a Ph.D. in science education. Mafor currently does research in technology-enhanced science education, the affordances of Virtual and Augmented Reality (VAR) in science teaching and learning, mobile learning in science education, and Inquiry-Based Science Education (IBSE). She has also published some of her work in reputable journals and various national and international conferences, including SAARMSTE (Southern African countries), ISTE (South Africa), ICET, ICPE, ICESS & END (International).