International Journal of Multidisciplinary Innovative Research
ISSN: 2583-0228 Volume 4, Number 4 (Oct' 2024) pp. 51-60
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https://www.ijmir.org
Article Received: 14 Sept' 2024; Accepted: 24 Sept' 2024.

Research Article

Enhancing Connected Learning for STEM (CL4STEM) Adoption: Insights into Bhutanese In-Service and Pre-Service Teachers' Perceptions and Implementation Challenges

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ABSTRACT: ***This study investigated the teachers' perceptions on the implementation of Connected Learning Initiative for Teacher Education for Mathematics and Science (CL4STEM) innovations among Bhutanese Secondary level teachers in Samtse Dzongkhag (district), using the Concerns-Based Adoption Model and Moore and Benbasat's seven characteristics of innovation framework. A mixed-methods approach was employed, incorporating quantitative data from online surveys, qualitative data from structured interviews, and observational data from classroom settings. The analysis highlighted distinct differences in perceptions between the two groups: in-service teachers exhibited higher concerns related to the practical integration of CL4STEM into their existing workloads, focusing on its impact on student learning and teaching practices. Conversely, pre-service teachers demonstrated greater interest in the informational and collaborative aspects of CL4STEM, emphasizing their need for knowledge acquisition and collaborative engagement. These findings underscore the necessity for tailored support strategies to address the specific needs of each group. These findings reveal the necessity for tailored support strategies to address the specific needs of each group. Recommendations include providing targeted professional development and practical tools for in-service teachers, and enhancing informational resources and collaborative opportunities for pre-service teachers. This study advances the understanding of how varying teacher groups interact with educational innovations and offers valuable insights for optimizing the implementation of CL4STEM across different educational contexts. Addressing challenges and ensuring continued support for teachers is crucial for successful implementation Connected Learning for STEM Education.***

KEYWORDS: ***Connected Learning for STEM, Concerns-Based Adoption Model, Innovation Characteristics Framework, Levels of Use, Stages of Concern, STEM Education, Teacher perceptions, Educational Innovation.***

INTRODUCTION

The Connected Learning for Science, Technology, Engineering, and Mathematics (CL4STEM) Education represents a cutting-edge paradigm that prioritises the integration of technology and innovative pedagogical strategies to create a dynamic and engaging learning experience. Designed specifically to enhance the capacities of secondary school teachers in Science and

Mathematics, CL4STEM fosters higher-order thinking alongside principles of inclusion and equity (HOTIE) within classroom settings. This initiative actively involves teachers in meticulously curated Open Educational Resources (OER)-based modules in Science and Mathematics, while also fostering their engagement in online Communities of Practice (CoP).

At its core, the CL4STEM endeavour seeks to bridge the gap between traditional didactic education and the evolving demands of the digital age by leveraging connectivity and interactivity. One of the key aspects of CL4STEM education is its emphasis on interconnectedness. Rather than viewing subjects such as science, technology, engineering, and mathematics as isolated disciplines, CL4STEM promotes an integrated approach where concepts from each STEM subject are interconnected and applied in real-world contexts. This interdisciplinary approach not only fosters a deeper understanding of STEM concepts but also mirrors how knowledge of these subjects is utilised in school settings (CL4STEM-Bhutan, 2023).

Technology is central to CL4STEM, serving as both a learning tool and collaborative platform. It facilitates hands-on exploration of complex STEM concepts through digital simulations, virtual labs, and interactive multimedia resources. Online platforms and communication tools foster collaboration among students and teachers, supporting a learner-centred approach that empowers students to take ownership of their learning journey. This emphasis on innovation and creativity prepares learners to adapt to the rapid advancements in technology (CL4STEM-Bhutan, 2023; Khushk et al., 2023).

In addition, CL4STEM places strong emphasis on inclusivity and diversity that aims to create an open and accessible learning environment. This fosters inclusivity and equity, thus enriches the educational experience by bringing together students from diverse backgrounds. Evaluating CL4STEM's effectiveness entails examining its alignment with current teaching methods, perceived advantages, and demonstrable outcomes in STEM education. This evaluation is crucial for informing educational policies and practices. Consequently, this study aims to investigate the perceptions and implementation levels of CL4STEM among secondary-level educators in Samtse district, Bhutan.

Research objectives

1. Evaluate how secondary science and mathematics teachers view CL4STEM's effectiveness in improving teaching and learning experiences.
2. Understand the readiness of teachers to adopt CL4STEM by examining their concerns and stages of adoption.
3. Identify the factors that help or hinder the implementation of CL4STEM in classrooms.

Research questions

i. How do science and mathematics teachers perceive the effectiveness of CL4STEM in enhancing teaching and learning experiences in their classrooms?

ii. What are the primary concerns of science and mathematics teachers regarding the adoption of CL4STEM, and how do these concerns evolve across different stages of adoption?

iii. What factors support or impede the effective implementation of CL4STEM in science and mathematics classrooms?

METHODOLOGY

Research Approach

This study utilizes the Concerns-Based Adoption Model (Hall & Hord, 1974) and Moore and Benbasat's (1991) seven characteristics of innovation framework as theoretical lenses to investigate the implementation of the CL4STEM innovation. The Concerns-Based Adoption Model framework offers insights into the various stages of concern that participants may experience during the adoption and integration of CL4STEM. In contrast, Moore and Benbasat's (1991) framework is employed to examine the attributes of the innovation that may affect its adoption. Table 1 presents the stages of concern, adapted from Hall and Hord (1974), while Figure 1 illustrates the seven characteristics of innovation, adapted from Moore and Benbasat (1991).

Table 1: Stages of concern for the Concerns-Based Adoption Model (adapted from Hall & Hord, 1974)

0. Unconcerned	Not interested to participate in CL4STEM
1. Informational	Know about CL4STEM, and would like to use at some point in time
2. Personal	Concerned about the demands of CL4STEM vis-a-vis existing workload and how it fits in the existing working conditions
3. Management	Grappling with how to effectively navigate the online modules and participate in the Telegram groups of CL4STEM
4. Consequence	Evaluating how CL4STEM teaching strategies impact/help in student learning
5. Collaboration	Exploring ways of collaboration with other teachers and educators to help impact student learning using CL4STEM teaching strategies
6. Refocusing	Exploring ways of improving CL4STEM teaching strategies through further refinement of the modules and CoP participation and/or alternative ways of achieving better results

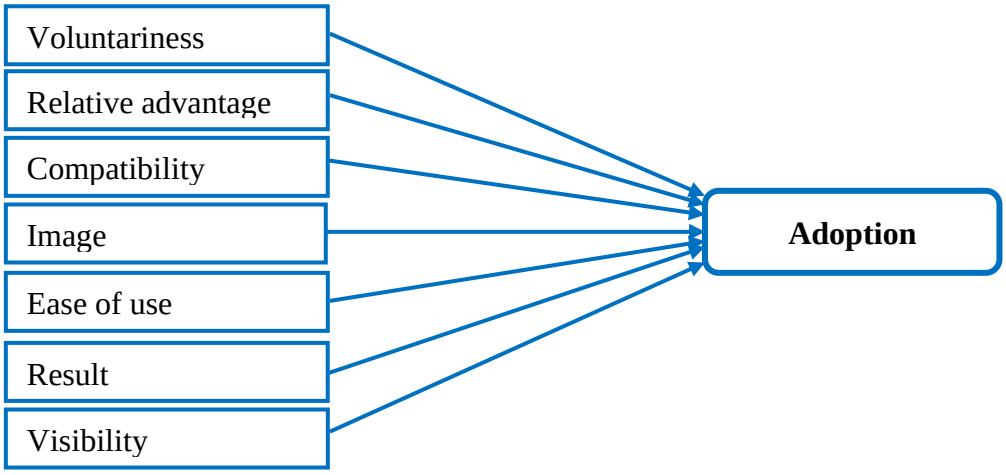

Figure 1: The Moore and Benbasat's (1991) seven characteristics of innovation framework.

Research Design

A mixed-methods approach was employed to investigate the implementation of the CL4STEM innovation. This involved gathering data from both qualitative and quantitative sources to provide a holistic understanding of the phenomenon. The study focused on in-service science and mathematics teachers, as well as pre-service student-teachers enrolled in the Postgraduate Diploma in Education (PgDE) Programme.

Sampling Strategy

The initial target population for this study comprised science and mathematics teachers employed in middle and higher secondary schools across 20 dzongkhags (districts). However, due to Covid-19 pandemic-related restrictions, the study was limited to the Samtse district, where seven secondary schools in southwest Bhutan were selected. Participants were selected through criterion-based purposive sampling. The sample consisted of three distinct groups of science and mathematics teachers: (i) the Intervention In-service Focus Group (teachers with less than 5 years of experience), (ii) the Intervention In-service General Group (teachers with more than 5 years of experience), and (iii) the Intervention Pre-service Group (PgDE students). A total of 82 participants were included in the study.

Data Collection Techniques and Procedure

Data were collected using both quantitative and qualitative methods. Quantitative data were obtained through online surveys administered via Google Forms, while qualitative data were collected through structured interviews conducted via Zoom and classroom observations. The data collection procedure involved distributing survey questionnaires to science and mathematics teachers. The survey included 23 items, rated on a 7-point Likert scale, with responses ranging from 1 (strongly disagree) to 7 (strongly agree). The survey assessed seven key themes such as voluntariness, relative advantage, compatibility, image, ease of use, results demonstrability, and visibility, based on Moore and Benbasat's (1991) seven characteristics of innovation framework.

Data Analysis

Quantitative data collected from online surveys were analyzed using descriptive statistics, which included measures of central tendency (mean, median, and mode), percentages, frequencies, and standard deviation. Qualitative data from Zoom interviews and classroom observations were analyzed using thematic analysis. A deductive approach was employed due to the presence of predetermined themes. The transcripts were systematically reviewed to identify recurring patterns and themes that aligned with the research objectives.

Validity and Reliability

The validity of the instruments was established through an expert review conducted by specialists from the Tata Institute of Social Sciences (TISS), Mumbai, India, and through pilot testing. This process ensured that the instruments accurately captured participants' perceptions and experiences. Additionally, the internal consistency reliability of the survey questionnaires was assessed to confirm the reliability of participants' responses.

RESULT AND DISCUSSION

Based on the findings from the data collected on the stages of concern regarding the CL4STEM innovation (Table 2), several critical insights emerge, essential for understanding and facilitating the adoption and implementation of educational innovations. The most notable

concern is the Consequence stage, which received the highest number of responses (19). This stage, as outlined in the Concerns-Based Adoption Model (Hall & Hord, 1974), highlights participants' focus on evaluating the effectiveness of CL4STEM strategies in improving student learning outcomes. This emphasis on impact is consistent with prior research that underscores the importance of evidence-based outcomes for the adoption of educational innovations (Rogers et al., 2014).

Following this, the personal stage, with 15 responses, reveals significant concerns about how CL4STEM will fit with existing workloads and working conditions. Hall and Hord (1974) suggest that such personal concerns are crucial because they can affect an individual's readiness to adopt new practices. This aligns with literature that indicates the need for support systems to address concerns about workload and integration to facilitate successful implementation (Vescio et al., 2008).

The prominence of the Refocusing stage, particularly among the Preservice group (9 responses), reflects a focus on refining CL4STEM strategies. As Hall and Hord (1974) note, this stage involves iterative improvements to enhance the effectiveness of the innovation. This finding supports research emphasizing the importance of ongoing professional development and feedback in refining instructional practices (Rogers, 2014).

Moreover, the significant attention given to the Collaboration stage (17 responses) underscores a strong desire for collaborative efforts among educators. Moore and Benbasat (1991) highlight the role of collaboration in the successful adoption of innovations. This finding is supported by recent studies that demonstrate how collaborative networks can facilitate the sharing of best practices and enhance the implementation of educational technologies (Vescio et al., 2008).

Overall, these findings suggest that addressing educators' concerns through targeted professional development, robust evaluation mechanisms, and fostering collaborative environments will be essential for the successful adoption and integration of the CL4STEM innovation. Providing structured support to alleviate personal concerns, demonstrating the impact of the innovation, and enhancing collaborative opportunities are critical strategies for advancing educational innovations.

Table 2: Collected Data on Stages of Concern for CL4STEM Adoption from the endline survey.

Overall stages of concern		Focus	General	Preservice	Total
0. Unconcerned	Not interested to participate in CL4STEM	0	0	1	1
1. Informational	Know about CL4STEM, and would like to use at some point in time	1	3	6	10
2. Personal	Concerned about the demands of CL4STEM vis-a-vis existing workload and how it fits in the existing working conditions	4	3	8	15
3. Management	Grappling with how to effectively navigate the online modules and participate in the Telegram groups of CL4STEM	1	0	3	4

Overall stages of concern		Focus	General	Preservice	Total
4. Consequence	Evaluating how CL4STEM teaching strategies impact/help in student learning	8	4	7	19
5. Collaboration	Exploring ways of collaboration with other teachers and educators to help impact student learning using CL4STEM teaching strategies	4	4	9	17
6. Refocusing	Exploring ways of improving CL4STEM teaching strategies through further refinement of the modules and CoP participation and/or alternative ways of achieving better results	1	6	9	16
	Total	**19**	**20**	**43**	**82**

The comparative mean perception data across focus groups (general, in-service, and pre-service) offers valuable insights into the differing attitudes and concerns regarding the CL4STEM innovation (Figure 2). The analysis reveals notable differences in perceptions between the in-service and pre-service groups.

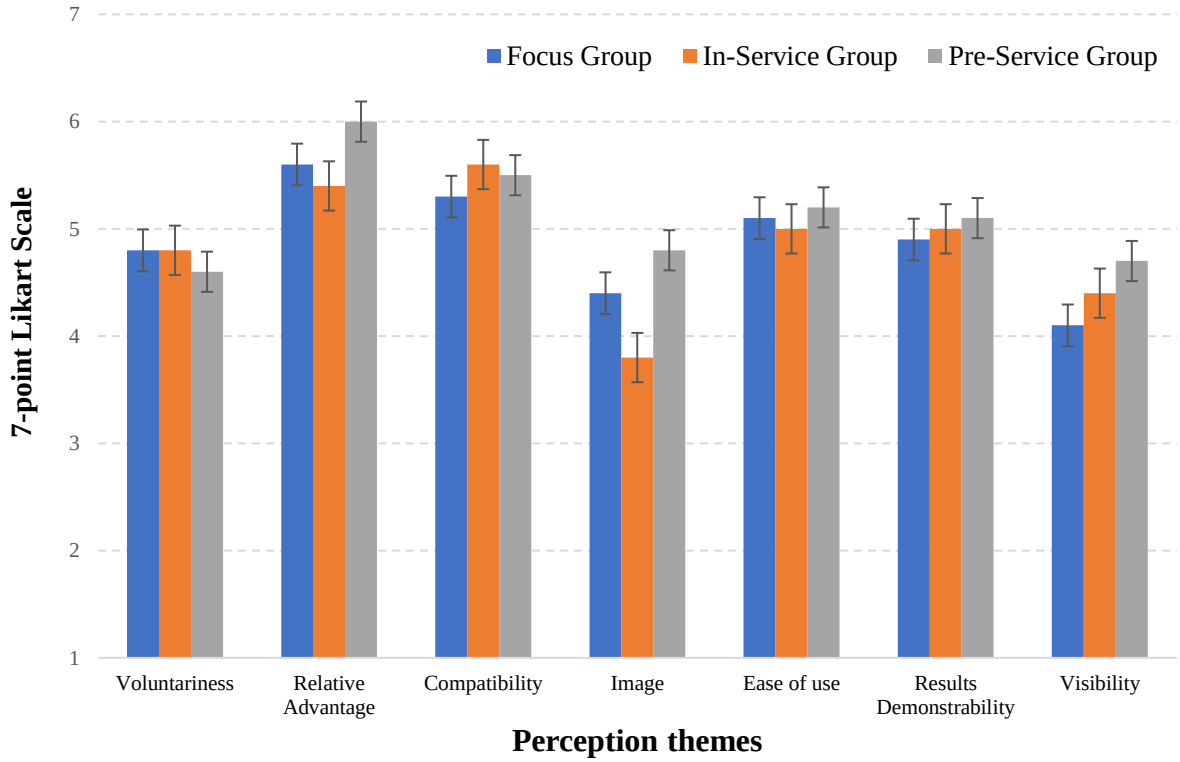

Figure 2: Comparative mean perception graphs across focus, in-service and pre-service groups

1. Voluntariness

The concept of voluntariness in the adoption of CL4STEM reflects teachers' perceptions of whether their participation is optional or mandatory. Data indicates that in-service teachers,

particularly those in the Management stage, express considerable concern about the voluntariness of CL4STEM, viewing it as an additional burden on their workload. Many in this group perceive the initiative as imposed rather than voluntary, leading to resistance and apprehension. Conversely, pre-service teachers demonstrate a more positive perception, seeing CL4STEM as a voluntary opportunity that can enhance their future teaching careers (Figure 2). This contrast aligns with Hall and Hord's (1974) Concerns-Based Adoption Model, which suggests that experienced teachers may exhibit greater resistance to innovations perceived as mandatory. Furthermore, initial participation in the CL4STEM project varied, with some teachers acknowledging that their involvement was not entirely voluntary but rather influenced by nominations from management or school authorities. This lack of complete voluntariness is consistent with findings that externally mandated participation can affect initial attitudes toward educational initiatives (Kirkpatrick & Kirkpatrick, 2016).

2. Relative Advantage

The theme of Relative Advantage evaluates the perceived benefits of CL4STEM compared to existing teaching methods. In-service teachers, particularly those in the Consequence and Refocusing stages, recognize significant potential for CL4STEM to enhance student learning outcomes, indicating a clear perception of its relative advantages. This is consistent with Rogers' (2014) diffusion of innovations theory, which suggests that experienced adopters, such as in-service teachers, require observable benefits to fully commit to new innovations. Conversely, pre-service teachers in the Informational stage are still exploring and understanding these benefits (Figure 2). Quantitative data further support these perceptions, revealing positive views on the advantages of CL4STEM, including more efficient teaching processes, improved teaching quality, and greater effectiveness. These findings align with previous research that underscores the benefits of collaborative learning approaches in advancing educational outcomes (Johnson et al., 2014).

3. Compatibility

This theme examines how well CL4STEM fits into teachers' existing practices. In-service teachers, particularly in the Personal and Management stages, express concerns about the compatibility of CL4STEM with their current workload and working conditions. They may find it challenging to integrate the new system into their established routines. In contrast, pre-service teachers in the Collaboration stage see CL4STEM as an opportunity to collaborate with other educators and integrate new teaching strategies, perceiving fewer compatibility issues (Figure 2). Moore and Benbasat (1991) emphasize that compatibility is a key factor influencing innovation adoption, and this difference is evident in how teachers with varying levels of experience view CL4STEM.

4. Image

The theme of image pertains to how the adoption of CL4STEM influences teachers' professional reputation. For in-service teachers, particularly those in the Consequence and Refocusing stages, there is a notable concern with how CL4STEM might enhance their image as competent and innovative educators. This concern reflects their desire to be recognized for integrating advanced practices and improving their teaching effectiveness. In contrast, pre-service teachers are less focused on this aspect, as they are primarily engaged in acquiring knowledge about CL4STEM rather than its impact on their professional status (Figure 2).

Quantitative data indicated a neutral perception regarding CL4STEM's effect on teachers' image. However, qualitative insights revealed that participants perceived limited elevation in

their status within their schools. This suggests that while CL4STEM might contribute to professional development, it has not directly translated into enhanced recognition or status. Such findings emphasize the need for educational initiatives to be accompanied by explicit mechanisms for acknowledging and rewarding teachers' contributions to ensure that improvements in professional image are realized (Vescio et al., 2008; Hargreaves & Fullan, 2015).

5. Ease of Use

The finding reveals that pre-service teachers, who are accustomed to using Virtual Learning Environments (VLEs) in their college courses, report fewer concerns about the ease of use of CL4STEM compared to in-service teachers. Their familiarity with VLEs likely enhances their perception of the system's usability. In contrast, in-service teachers, who have limited recent experience with online tools due to the lack of VLEs in their schools, encounter more difficulties in adapting to CL4STEM. This difference highlights the influence of prior exposure to similar technologies on ease-of-use perceptions. It suggests that familiarity with online learning environments, gained through college experience, significantly aids teachers in managing new systems (Ertmer & Ottenbreit-Leftwich, 2010).

6. Results Demonstrability

This theme examines the perceived ability of CL4STEM to produce tangible results, such as improved student outcomes. In-service teachers, particularly those in the Consequence stage, demonstrate a strong interest in understanding how CL4STEM impacts student learning, as indicated by their higher mean perceptions in this stage (Figure 2). This focus aligns with the Concerns-Based Adoption Model, which highlights that teacher in later stages, such as Consequence and Refocusing, are more concerned with the concrete outcomes of an innovation (Hall & Hord, 1974). Conversely, pre-service teachers, who are still learning how to implement CL4STEM, may not yet have sufficient experience to evaluate its effectiveness. Additionally, while teachers generally express confidence in their ability to communicate the benefits of CL4STEM practices to their peers, challenges remain in articulating the underlying rationale behind these practices. This underscores the need for clearer communication strategies to enhance the dissemination and adoption of innovative educational practices (Rogers et al., 2014). Effective knowledge dissemination is crucial in ensuring that the advantages of CL4STEM are well understood and leveraged by all educators.

7. Visibility

Visibility, or the extent to which CL4STEM's outcomes are observable in the classroom, has shown a positive trend in its adoption among teachers. In-service teachers, with higher scores in the Collaboration and Consequence stages, focus on the tangible improvements in student learning, aligning with Rogers et al. (2014) view that visible results facilitate adoption. Conversely, pre-service teachers, though enthusiastic about collaborative opportunities, lack the classroom experience to fully assess CL4STEM's impact, as reflected in their higher scores in the Collaboration stage (Figure 2). Qualitative data highlight that visibility is enhanced through collaborative efforts and knowledge exchange, underscoring the role of social networks in the diffusion of educational innovations (Borgatti et al., 2009).

General Perception Trends

The mean perceptions across focus groups reveal distinct trends between in-service and pre-service teachers. In-service teachers show higher mean scores in the Consequence and

Refocusing stages, indicating a greater emphasis on evaluating the impact of CL4STEM on student learning and refining teaching practices. This trend aligns with Rogers and frinds' (2014) diffusion theory, which emphasizes the importance of perceived benefits and practical applications in the adoption of innovations.

In-service teachers also report higher mean perceptions in the Personal and Management stages compared to pre-service teachers. This suggests that they face more significant concerns regarding how CL4STEM fits into their existing workload and the navigation of online modules. Hall and Hord (1974) highlight that personal and management concerns are critical barriers in the adoption process, indicating that in-service teachers may require additional support to address these challenges effectively.

Conversely, pre-service teachers exhibit higher mean perceptions in the Informational and Collaboration stages. This reflects their focus on acquiring knowledge about CL4STEM and exploring collaborative opportunities. Moore and Benbasat (1991) argue that informational and collaborative aspects are vital for early adopters and novices, who prioritize understanding new innovations and building supportive networks.

The comparative analysis suggests that differences in mean perceptions are influenced by the varying levels of experience and involvement between the groups. In-service teachers, with established practices, focus more on the practical implications of CL4STEM, while pre-service teachers, in the learning phase, emphasize acquiring new knowledge and peer engagement. This distinction supports the findings of Vescio et al. (2008), which stress the importance of addressing the distinct needs and concerns of different stakeholder groups when implementing educational innovations.

CONCLUSION

The key findings from the data reveal notable differences in perceptions of CL4STEM between in-service and pre-service teachers. In-service teachers demonstrate a greater focus on the practical impacts of CL4STEM, as evidenced by higher mean scores in the Consequence and Refocusing stages, reflecting their emphasis on student learning outcomes and refinement of teaching practices. They also express more concerns in the Personal and Management stages, indicating challenges related to workload integration and module navigation. Conversely, pre-service teachers show higher engagement in the Informational and Collaboration stages, highlighting their interest in acquiring knowledge and exploring collaborative opportunities. These findings underscore the varying needs and concerns of each group, aligning with Rogers' diffusion theory, which stresses the importance of visible benefits and practical applications for innovation adoption, and supported by Hall and Hord's (1974) emphasis on addressing personal and management concerns as barriers to adoption and Moore and Benbasat's (1991) focus on the significance of information and collaboration for early adopters.

Overall, the implementation of CL4STEM represents a forward-thinking approach to STEM education that harnesses the power of technology and innovative pedagogies to prepare students for success in the digital age. By fostering collaboration, creativity, and critical thinking, CL4STEM empowers learners to become active participants in shaping the future of science, technology, engineering and mathematics.

DISCLAIMERS

The views expressed herein do not necessarily represent those of International Development Research Centre (IDRC) or its Board of Governors.

ACKNOWLEDGMENT

This work was supported by the Global Partnership for Education Knowledge and Innovation Exchange, a joint endeavour with the International Development Research Centre (IDRC), Canada.

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