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Multiple iterations and messiness in the implementation of action research by Bhutanese secondary science teachers

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Abstract
Many theoretical models of action research depict its process as cycles that include several sequential phases. In Bhutan, teachers use Kemmis and McTaggart's spiral model which has four phases of *plan, act, observe* and *reflect* to conduct action research for their professional learning. As a growing practice, the way Bhutanese teachers carry out action research is an emerging field of inquiry. This study explored how three Bhutanese secondary science teachers in a case study school conducted their first action research project using Kemmis and McTaggart's model to improve student interaction in the class. Data were collected using diaries, interviews and observations. The analysis employed a three-step coding procedure of grounded theory. The findings showed that the science teachers conducted multiple iterations by moving back-and-forth between the four phases of Kemmis and McTaggart's model. It demonstrated a messy and non-linear process of action research conducted through continuous reflection which was inconsistent with the neat cycles of Kemmis and McTaggart's model. Despite a few challenges, the multiple iterations and continuous reflection helped the teachers to make progress in their action research and develop an interactive teaching strategy. Given the absence of multiple iterations and messiness in the action research knowledge disseminated to teachers in Bhutan, the study highlights the requirement for the Ministry of Education and teachers to consider mess and multiple iterations as a normal process of action research.

Keywords Action research · Bhutan · Messy process · Multiple iterations · Science teachers

1 Introduction

In the years following the origin of action research in 1946 through the works of Kurt Lewin in the USA, it has become a full-grown international movement sustained by many teachers, teacher educators and educational researchers in various countries [37]. International research on science teachers' use of action research is replete with evidence demonstrating action research as a useful framework to improve teaching practices, teacher professional development, curriculum development and reflective abilities [4, 8, 9, 11, 20]. However, teachers' use of action research in the context of science education in Bhutan, a Buddhist country between India and China, is not widespread and remains an emergent field of inquiry. As a developing country, raising the quality of science education has gained attention to build students' scientific knowledge and skills to facilitate the country's socio-economic progress [29]. Science education is offered through a centralized science curriculum and students' learning is assessed through standardized tests. There is a growing interest in Science Technology Engineering and Mathematics (STEM) education as an alternative to the

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independent subject-based curriculum [29]. Efforts are geared towards raising the teaching practices to improve the quality of STEM education. The Ministry of Education (MoE) promulgates teachers' use of action research as one of the strategies to enhance their teaching practices and professional learning. The MoE [26] considers action research as a teacher-driven and school-based professional development tool and encourages teachers to conduct action research to address the context-specific issues they face in their teaching. The Bhutan Education Blueprint 2014–2024, a 10 year education reform roadmap formulated by the MoE [27, p.12] recognises action research as one of the "game-changing professional development tools" for teachers and recommends every teacher carry out action research. In 2018, the government launched the *Sherig* endowment fund to support teachers' AR projects in schools [33].

In this effort, the Ministry of Education (MoE) has adopted Kemmis and McTaggart's [15] action research model developed at Deakin University in Australia to guide teachers to conduct action research [33]. The model has a spiral pathway with each cycle consisting of *plan, act, observe* and *reflect* phases. It depicts action research as a linear and forward-moving process with one phase leading to the other. The model was used as a framework to develop a handbook for teachers by the Royal Education Council (REC) in 2018 that explains the steps to conduct the *plan*, *act*, *observe* and *act* phases. The handbook describes neat cycles of the four phases. As a growing practice, action research is a new concept for most science teachers and there is limited professional development to facilitate their understanding of the process.

Most studies on science teachers' application of action research are conducted in western countries such as the USA, the UK, Australia, Canada, and Germany [5, 6, 9, 13, 20, 34] and Asian countries such as Singapore, Thailand, Pakistan, Malaysia, the Philippines, Indonesia, China, [8, 11, 17, 37]. In Bhutan, a few studies have been conducted by Rabgay and Kidman [31]; Wangdi and Tharchen [40]; and Timsina, [39] exploring the constraining and enabling factors of carrying out action research in schools. However, these studies have not investigated how Bhutanese secondary science teachers carry out the process of action research. Despite a lack of studies on the action research process implemented by Bhutanese science teachers, the REC and MoE have made several assumptions about action research in their planning and policy documents. The REC [33] assumes action research as a linear process and a "powerful strategy that can be used by teachers to study their own pedagogical practices, implement interventions to improve upon, and refine their pedagogical practices" (p. iv). The MoE [26] regards action research as an effective tool for teachers to "improve their teaching skills and to enhance student learning" (p. 222) and associates teachers' ability to conduct "research and utilisation of relevant findings" with the qualities of a "Distinguished Teacher" [28, p. 42]. These beliefs about the linear process of action research and its influence on teachers need to be verified by studies exploring how Bhutanese Science teachers carry out the process of action research. Particularly, there is a requirement for an investigation into how teachers carry out each phase of Kemmis and McTaggart's [15] model to facilitate the MoE to take further actions to support science teachers' use of action research. Therefore, the purpose of the study was to explore how Bhutanese secondary Science teachers carry out the four phases of Kemmis and McTagart's [15] model. The research question that guided this study was: How do Bhutanese secondary science teachers carry out action research using Kemmis and McTaggart's [15] model?

2 Literature review

2.1 Action research for science teachers

Kemmis and McTaggart [15, p. 5] defined action research based on collaboration and self-reflection as "a collective self-reflective inquiry undertaken by the participants in the social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out". Recently, Kemmis et al. [16] and in the past, Carr and Kemmis [5]; and Kemmis and McTaggart [15] viewed action research from a critical theorist perspective. The authors reject the positivist view of research that the researchers take an objective stance as an observer whose self-interest does not affect the research. The authors claim that research is valued-laden and influenced by the critical self-reflection of an individual or a collective group. The authors argue that critical self-reflection allows an individual or a group to actively interrogate their practices, the result of their practices and the conditions under which they practice. This leads an individual or a group to understand and discover whether their practices and conditions are rationale, sustainable and just [16]. Located within the framework of critical theory, action research emphasises the liberating function of enhancing democracy in schools and society [15]. The authors encourage teachers to critically reflect and interrogate their practices analyse their situations to gain new ways of understanding and take action to transform their practices and situations for students, teachers, and society.

For several reasons, action research has gained widespread recognition as an effective tool for science teachers' professional development [37, 41]. A primary reason for its effectiveness in science teachers' professional growth is that it provides the structure to improve their teaching practices and student learning [4, 19]. This is demonstrated by several international studies. In Thailand, Kijkuakul [17] investigated how three science teachers from different schools and districts carried out collaborative action research using Kemmis and McTaggart's [15] model. The study found that one of the participants was able to shift from lecture method teaching to the use of experimentation and classroom discussion, fulfilling the demands of the national science curriculum standards. Similarly, in Singapore, Fernandez's [11] action research helped in gaining an understanding that secondary physics teachers' use of Authentic Inquiry-Based Instruction (AIBI) was more effective than Traditional-Physics Instruction (TPI) in facilitating students' conceptual understanding of thermal physics. Likewise, in the USA, Lebak and Tinsley [20] reported that action research helped the three science teachers to change their pedagogical approach from teacher-centred and textbook-driven teaching to student-centred and inquiry-based teaching.

Besides improving practice, researchers such as McNiff and Whitehead [23] and Mertler [24] describe action research as a tool to foster teachers' reflective thinking. The authors explain that reflection is the first step in action research and sustains till the end, which leads to improving teachers' practices or solving practical problems. Schon [36] claims that the notion of a reflective practitioner challenges the conventional view of the teacher's role as a technical implementer of knowledge generated by others. Eilks and Markic's [9] study of collaborative action research between science education researchers and practising chemistry teachers in Germany found that the teachers were able to develop reflective abilities and become key players and self-determined causes of change in teaching practices. Likewise, Dean's [8] comparison of the influence of action research on teachers in schools in Asia, East Africa, and Central Asia also revealed action research is a valuable strategy for teachers to develop their reflective abilities.

2.2 Action research as an iterative process

Proponents of action research such as Lewin [21], Kemmis and McTaggart [15] and Mills [25], described action research as a form of inquiry comprising a series of iterative cycles each leading to and informing the next until teachers achieve satisfactory outcomes. This continuous systematic process allows teachers to have a sustained focus on the issue, engage in constant self-reflection, gain a better understanding of their practice, and refine ideas and practices through each cycle [1, 2]. The iterative process of action research leads to raising the rigour of research because it allows researchers to broaden their understanding of a focus issue, collect cumulative data and strengthen the findings by building on evidence gathered from previous iterations [10, 18].

The iterative process is depicted in various action research models developed by Lewin [21]; Kemmis and McTaggart [15], and Mertler [24]. Lewin [21] who is credited for the origin of cation research developed an iterative model of action research with each cycle composed of general planning, acting, and fact-finding or reconnaissance of results. Lewin [21] challenged the traditional scientific research paradigm that lacked the capacity to generate knowledge for use by members of organisations and proposed action research as a research paradigm and an iterative process to produce actionable or practical knowledge to address social issues. Kemmis and McTaggart [15] developed a cyclical model, comprising four phases: *Plan, act, observe* and *reflect*. This model, which is used in Bhutan, focuses on collaboration and critical self-reflection and the iterative process continues until a group of action researchers achieve satisfactory results. In the *plan* phase, a group of teachers identify issues or questions in their teaching practices or student learning and devise a plan of action to improve or address the problem. In the *act* phase, teachers systematically implement the plan. The *observe* phase involves recording and analysing the data to understand and assess the effects of the action. In the *reflect* phase, teachers interpret the information, ask questions about their action, build a shared understanding of what happened, take stock of the overall learning from the project, and decide whether to conduct the second cycle [15]. In their more recent work, Kemmis et al. [16] developed a new model showing an infinite number of cycles of *plan, act, observe* and *reflect*. However, teachers in Bhutan are encouraged to use the former version as it is a seminal model that succinctly summarises the essential phases of action research.

Other action research models such as Mertler's [24] and Sagor's [35] model also represent a cyclical process. Sagor [35] designed an iterative model for conducting school-based collaborative action research. The action research process in this model comprises five steps which are: *problem formulation, data collection, data analysis, reporting of results, and action planning*. He claimed that action research within this model is conducted collaboratively and leads to the development of an active community of professionals, overcomes professional isolation and promotes values such as respect for team members' professionalism, intelligence, and decision-making abilities. Likewise, Mertler's [24] model

has four major stages, namely, *planning, acting, developing, and reflecting*, which was designed to improve teachers' educational practice, reflective ability, and confidence; empower teachers as decision-makers; and enable teachers to connect theory to practice.

2.3 Mess in action research

Although action research models developed by Lewin [21], Kemmis and McTaggart [15] Mertler's [24] and Sagor [35] succinctly summarise the essential phases of action research arranged in a neat, sequential, forward-moving, and cyclical pathway, Kemmis et al. [16] suggested that these framing concepts should not be misconstrued as rigid structural tenets for action researchers to doggedly follow. Furthermore, the authors explained that, in reality, action research is rarely as neat as the spiral of cycles and the process is likely to be a more non-linear, fluid, open and responsive that involves overlap of phases or looping back-and-forth between phases. Some models like Calhoun's [3] and Mills' [25] models already show the non-linear process. Calhoun's [3] model presents action research as a five steps process composed of: *select area of focus, collect data, organise data, analyse and interpret data*, and *take action*, with a back-and-forth movement between the five stages. Mills [25] designed a model with four steps: *Identify an area of focus, collect data, analyse and interpret data,* and *develop an action plan*. The model depicts a back-and-forth movement between *data collection*, *identifying an area of focus* and *data analysis*.

Cook [7, p. 3] used the term "mess" to describe the non-linear and flexible process of action research and attributed it to real-life and contextual issues faced by researchers that are seldom direct and linear. Goodnough [13] pointed out that it is an inherent and often necessary element part of the sense-making process that leads to creativity and originality in research. Similarly, Cook [6] argued that strictly following the research structure as portrayed in the action research models risks narrowing the focus of the research work and the opportunities for developing original and novel pathways. Cook [7] proposes that messiness in action research leads to enhancing interpretive and methodological rigor. The messy process leads to interpretive rigor because it creates a communicative space for the researchers to collaborate, exchange critical perspectives and argumentative interpretations and delve deep into theory and practice rather than superficial knowledge. The messy process enhances methodological rigor through its multiple iterations that provide opportunities for the researchers to collect cumulative data and thus strengthen the research findings by building on the data collected from the previous cycle. Hence, Cook [6] suggests that mess needs to be candidly and expansively reported in action research publications as a valuable part of the process and to give a real sense of the research process itself.

Whitehead [42] and Cook [6] observed that when researchers experience the messy process of action research, it becomes a time-consuming activity and often leads to multiple emotions. Cook [7] suggests that the messy area can be professionally and personally uncomfortable and tends to have connotations of being sloppy and not being a good researcher. Whitehead [42, p. 4] noted that the messiness of the research process leads to feelings of uncertainty, frustration, disorientation and being overwhelmed by a feeling of not doing it correctly. Fitzgerald et al. [12] also recorded their frustrations, highs, lows, and confusion when they experienced the messiness in the action research they conducted. Moreover, Goodnough's [13] study exploring two middle-school science teachers' experience of carrying out participatory action research for the first time in Canada, showed that the teachers were challenged by feelings of uncertainty and low confidence to follow the action research process. Furthermore, Rust and Meyers' [34] study in the USA examined four action research projects conducted by teachers at the Teachers Network Leadership Institute (TNLI) and concluded that the teachers felt intimidated and anxious about the complexity of the action research process.

However, Whitehead [42] and Goodnough [13] noted that the messiness and uncertainty faced by action researchers are rarely reported in most published accounts. The authors observed that action research publications report only the tidied-up process giving a false impression of action research as a neat, fully cyclical and forward-moving process. By tidying away the messy area, the research reports conceal the valuable part of the research process itself and give a false sense of what it is like to carry it out [13]. "If we miss out the 'messy' bit, if we tidy everything up to fit in a system, the creative part of our work can be lost" [6, p. 106]. A few publications have, however, reported the intricate process of action research. In a personal account of carrying out action research, Cook [6] reported on the experiences of a team of novice researchers experiencing messiness and feelings of uncertainty and being non-progressive. Fitzgerald et al. [12] reflect on the experiences of engaging in action research in the context of physical education. They noted recurring accounts of messy processes while negotiating access and developing relationships with research participants. Halai's [14] meta-synthesis of 20 action research theses written by Master of Education teachers in Pakistan concluded that teachers viewed action research as a messy and difficult-to-understand process. Since most of the teachers carried out action research for the first time, Halai [14] noted that they faced challenges in designing research tools and collecting

data due to a lack of knowledge. While past studies conducted in many countries have invariably shown messiness in implementing action research, it is unclear if a mess occurs when Bhutanese teachers carry out action research. This study attempted to fill this gap by exploring how Bhutanese teachers carry out Kemmis and McTaggart's [15] model advocated by the MoE.

3 Methodology

To develop an in-depth understanding of how Bhutanese secondary science teachers carry out the *plan, act, observe* and *reflect* phases of Kemmis and McTaggart's [15] model, we focused on a single case study school in Samtse District referred to as Drelwa MSS (pseudonym). Cases study approach was suitable because it enabled researchers to gain an in-depth understanding of a phenomenon by focusing on a small number of individuals [43]. Three science teachers in the school volunteered to participate in the study. The three science teachers are referred to as Sangay, Jimba, and Yangzom (pseudonym). We adopted grounded theory [38] to collect and analyse data as the three teachers carried out their action research. By adopting grounded theory, we could explore the experiences, voices, and reflections of the participants as they carried out their action research. Before data collection, we conducted a one-day action research workshop for the teacher participants on the steps of Kemmis and McTaggart's [15] model. Following the workshop, the teacher participants carried out collaborative action research on, *Enhancing classroom interaction in ninth-grade Biology*.

Data were collected progressively along the teachers' action research journey, using interviews, teachers' diaries, and participant observations. Four group interviews were conducted in the *plan* phase, eight in the *act* phase, three in the *observe* phase and two in the *reflect* phase. The interviews were audiotaped and transcribed for analysis. The teachers maintained a diary from the beginning to the end of the action research to record their feelings and reflective thoughts. An observation form was used in the *act* phase to collect data on how the teachers implemented their action research plan in the classrooms. Observation notes were also taken when the teachers had meetings. Data were analysed using the coding procedures of grounded theory: open coding, axial coding, and selective coding [38]. This coding process was done in the sequence of the four phases of Kemmis and McTaggart's [15] model. In open coding, the interview transcripts, summaries of diary entries and observation notes were coded line by line and some in segments. In axial coding, relationships were identified among the open codes by constant comparison to find the similarities and differences in terms of the properties and dimensions of the open codes. In selective coding, the axial categories were examined to identify a general pattern that linked the axial categories.

4 Findings: cycles within cycles

A major finding of the study was that the three science teachers at Drelwa Middle Secondary School conducted several iterations as they moved back-and-forth between the *plan, act, observe* and *reflect* phases of Kemmis and McTaggart's [15] model. Such steps created several mini-cycles within Kemmis and McTaggart's [15] cycle as shown in Fig. 1, making the entire process messy and non-linear. However, carrying out multiple iterations was beneficial as the teachers could make progress with each iteration and continuous reflection to develop a teaching strategy that raised student interaction. The multiple iterations conducted in each phase are described in the following sections.

4.1 Iterations in the plan phase

In the *plan* phase, the teachers identified the area of focus, formulated a research question, and created a plan to improve students' interaction in the class. As shown by the blue arrows in Fig. 1, these steps were undertaken in five iterations. The first iteration was conducted as the teachers changed the areas of focus three times. As listed in my observation notebook, the teachers initially proposed two possible topics related to teaching ninth-grade Biology: "*students' poor participation in the class and students' low levels of interest in learning Biology*". However, observation of the first two meetings showed that the teachers were unsure of which area would be researchable. In an interview, Sangay said, "Since we are doing it for the first time, we are not sure which one would be good for our AR". At the third meeting, the teachers decided to choose '*Student's low level of motivation to learn Biology*'. However, in an interview following the meeting, Sangay shared that "motivation is an abstract concept and difficult to measure." In the fourth meeting, the group changed the area to '*Students' low levels of interest in learning Biology*.' In the subsequent interview, Sangay and Jimba shared

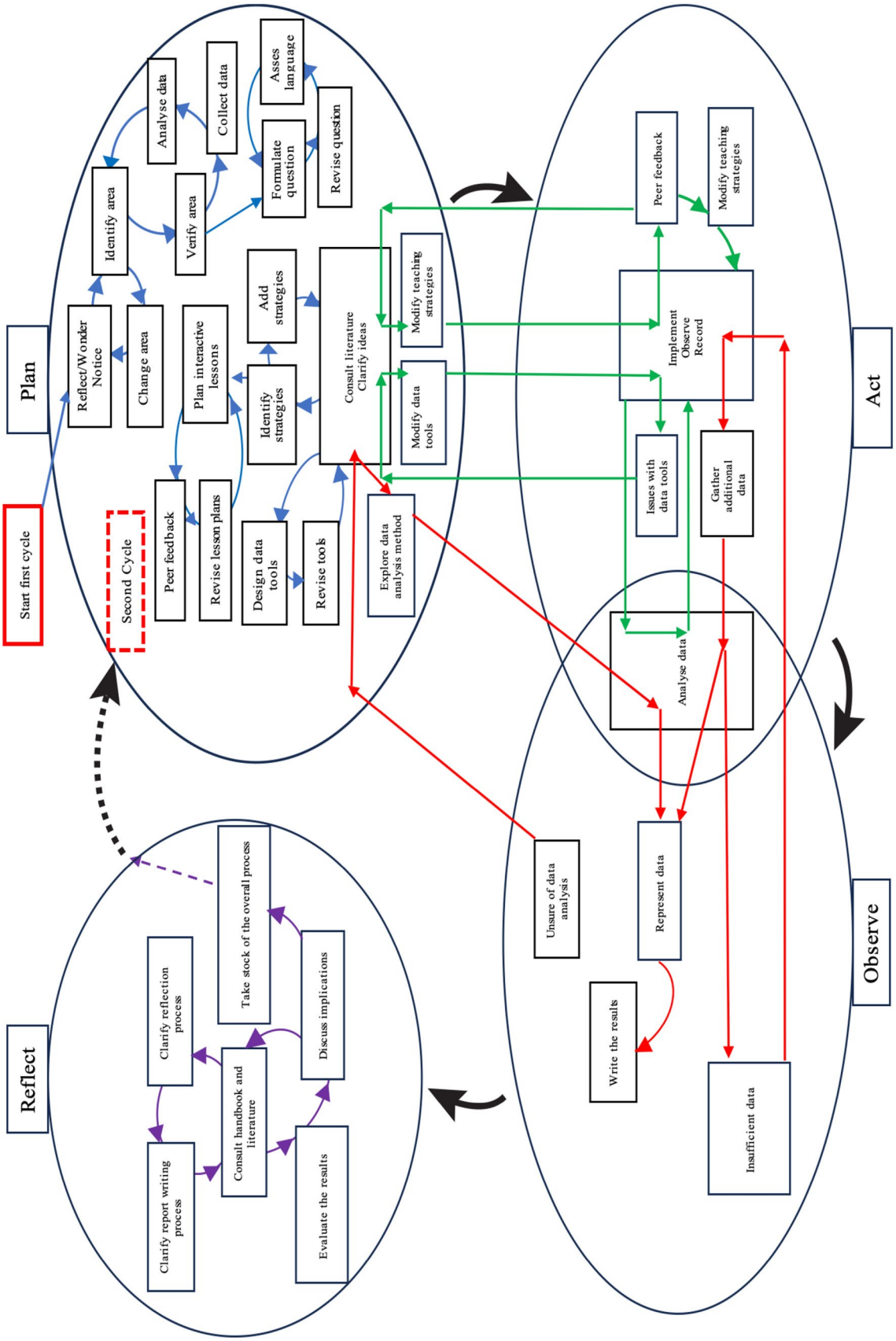

Fig. 1 Multiple iterations and messy process of action research conducted by the three teachers

that they verified their topic by collecting students' written views on their interest in learning Biology. Upon analysing students' views, the teachers found that "most students did not express a lack of interest in Biology subject" and Sangay and Yangzom described it as an "unrealistic topic". Eventually, the teachers chose "*Enhancing student interaction in the Class"* as their area of focus. The teachers also validated this area by asking a few questions to a group of students.

The second iteration was noted when the teachers refined their research questions for four times. Yangzom and Jimba's diary entries showed that they proposed, "*How can we enhance classroom interaction?"* as the research question. As shown by Sangay's dairy, this question was revised as "*What strategies can we use to enhance classroom interaction?"* Jimba's diary showed that the question was further revised as *"How can we change the level of classroom interaction in the class?"* Sangay suggested that they need to include the class and subject in their question to make it specific. They eventually agreed to the question, "*How can we enhance classroom interaction in the ninth-grade Biology class?*".

After confirming the focus area and inquiry question, the teachers devised a plan of action to improve student interactions in the class. The third iteration was observed as the teachers moved back-and-forth between exploring ideas in the literature and identifying interactive teaching strategies. The teachers used the Internet to read research literature and found three interactive teaching strategies, "Questioning technique, Reinforcement strategy, and Collaborative group activity" (Jimba's diary). Jimba shared thoughts about this plan in an interview, "We want to see if these would help our students to interact in the class. One of us will implement the teaching strategies, and the other two will observe the lessons". However, in the next meeting, the teachers expressed the need for additional strategies. Jimba pointed out that "they may have to carry out more than three lessons to effectively improve student interaction". After spending two days searching for additional strategies on the Internet, they added "Reward strategy and project method" (Jimba's diary) and planned the lesson, which was a back-and-forth step between exploration and planning.

The fourth iteration occurred when the teachers repeatedly sought feedback and revised the written lesson plans. Jimba wrote the lesson plans outlining the steps to implement questioning and collaborative group activity. Upon discussing the lesson plans, Sangay and Yangzom suggested a couple of changes. As noted in my observation notebook, Yangzom mentioned that the "procedures of collaborative group activity need re-sequencing." Sangay noticed that "the questioning method included only a few students" and suggested that "more student-to-student questioning be included". Accordingly, Sangay revised the lessons and shared his thoughts on this back-and-forth step in an interview, "I am redesigning the lesson plans. It is taking a long time. I will try to finish it as soon as possible".

The fifth iteration was observed when Sangay repeatedly modified the data collection tools by seeking ideas from the literature. The group decided to design an observation form to collect data on student interactions and a questionnaire to record students' views of interacting in the class. Sangay created several drafts of the data collection tools. However, he felt uncertain due to his inadequate knowledge of designing both tools as evidenced by his diary, "Since I have not done this before. I am not sure if the questionnaire and observation sheet I have developed will work".

4.2 Iterations in the act phase

In the *act* phase, the teachers implemented the interactive teaching strategies, observed the effects, collected data, and modified the teaching strategies to enhance students' classroom interaction. As shown by the green arrows in Fig. 1, these steps were done in four iterations as they moved back-and-forth between the *plan* and *act* phases.

The first iteration was observed when the teachers revised the first interactive teaching strategy using questioning and verbal reinforcement taking a return step to the *plan* phase and implementing it, taking a forward step to the *act* phase. Jimba implemented the interactive teaching strategies while Sangay and Yangzom observed and provided feedback on the effects of the teaching strategies. After Jimba implemented the questioning and verbal reinforcement strategy to teach the concept of transpiration, Sangay and Yangzom pointed out that the lesson hardly went as planned and expected. Sangay suggested that "the students were just responding to the teacher's questions. They did not ask questions or share ideas, plus, Jimba was a bit strict, and students hesitated to ask questions". Jimba revised the lesson plan based on Sangay and Yangzom's feedback. Subsequently, the teachers observed positive changes as noted in Yangzom's diary, "Jimba showed friendly behaviour and the students were actively engaged in asking questions to each other".

Likewise, the second iteration was observed when the teacher modified the use of paper stars as a reinforcement strategy to teach the figure of stomata in leaves. Sangay and Yangzom observed that the use of paper stars was ineffective. Yangzom raised this concern in an interview, "The paper stars hardly motivate the students to interact. They are just papers and students do not take them seriously. We need a different reinforcement technique". The teachers were frustrated with this observation and were unsure of the next step. They felt that their project was chaotic. Jimba and Sangay's diary revealed thoughts of giving up. Jimba wrote, "We have messed up. It's not going as per our plan and

expectation. I feel like quitting". Sangay wrote, "It is getting complicated. We are concerned about the mid-year exam which is close. I think we must stop here". However, the teachers moved on. In the following meeting, it was observed that Sangay read some literature and suggested replacing paper stars with awarding points to students who interacted with the teachers and peers. Accordingly, Jimba re-planned the lesson and implemented it, which Sangay noted in his diary as "more effective compared to paper stars".

Similarly, the third iteration was observed when the teachers modified the collaborative group teaching strategy to teach the concept of Photosynthesis. Sangay and Yangzom observed limited student interaction when using this strategy. After reading some action research articles obtained from the Internet, Yangzom suggested combining group activity, questioning and reinforcement methods". In the interview following the implementation of the combined teaching strategy, Sangay shared, "It is good to observe students talking to each other by asking questions". The teachers implemented three more interactive teaching strategies that did not require modifications.

The fourth iteration was noted when the teachers took a return step to the *plan* phase and a forward step to *act* phase to revise the data collection tool. After implementing the second interactive teaching strategy using paper stars, Sangay and Yangzom noticed that the observation form was not suited to recording classroom interaction and needed revision. Yangzom said in an interview, "It just has two columns to record student activity and teacher activity. It needs more rows to record various kinds of interactions with a tick". Subsequently, Sangay explored the literature, found a sample observation form, and revised it.

It was observed that the teachers conducted a preliminary data analysis in the classroom while Jimba was implementing the teaching strategies. Undertaking this dual step of implementing the teaching strategies and analysing the data indicated an overlapping process of the *act* and *observe* phases as shown in Fig. 1. This action was recorded in our observation notebook "Sangay and Yangzom observe and compare their data in the class while Jimba keeps teaching".

4.3 Iterations in the observe phase

In the *observe* phase, the teachers analysed the data to assess the effects of the interactive teaching strategies. As shown by the red arrows in Fig. 1, two iterative cycles were conducted in this phase. The first iteration was conducted when the teachers explored the literature to create a plan to analyse the data. This was a backtracking step to the *plan* phase. Then the teachers refocused on data analyses, which was a return step to the *observe* phase creating a mini cycle. The teachers struggled to organise and analyse the data. After reading the literature, they met in the school conference hall. Sangay displayed the research articles using a projector and identified mean and standard deviation to analyse the quantitative data and thematic analysis method to analyse the qualitative data. The following entry in Sangay's diary evidenced this step, "In the afternoon, we were free, and we gathered in the conference hall and learnt about mean, standard deviation and thematic analysis to analyse our data". Then the teachers analysed and represented the data.

The second iteration occurred when the teachers implemented additional lessons to gather more data. The teachers realised that they did not have enough data to assess the effects of the interactive teaching strategies. Subsequently, the teachers planned and implemented two more lessons to collect additional data as evidenced by my observation notebook, "The first extra lesson is conducted using questioning and reinforcement strategy. The second is a combination of group activity, questioning and reinforcement methods". This was another backtracking step to the *plan* and *act* phase from the *observe* phase.

4.4 Iterations in the reflect phase

In the *reflect* phase, the teachers clarified the process of reflection. The teachers then took stock of the entire process they undertook, discussed the factors that influenced their efforts and proposed a possible second cycle. As shown by the purple arrows in Fig. 1, two iterations were observed in carrying out these steps. The first iteration was noted when the teachers sought clarification of the reflection process by reading the handbook and the workshop notes. My observation of a group meeting stated, "The teachers meet after school and read the handbook on the reflection process. Yangzom read the notes she had written during the workshop". The teachers were also unsure of how to write their reflections in their action research report. They read a few research articles to gain some ideas. Sangay who took up the role of writing the report said in an interview "We were wondering how to put our reflective ideas in the report. But we found some ideas from published reports".

The second iteration was observed for the teachers' evaluation of the results of the data analysis and their retrospective reflection on the action research process. Focusing on the results related to the most common interaction, Sangay

said, "The mean shows that there was minimum student-initiated interaction compared to teacher-initiated interaction". Yangzom shared the implication of using the new interactive teaching method, "The thematic analysis shows that students liked to interact when questioning method with stars and badges were used. This means we must use this strategy most of the time". Reflecting on the process, Sangay said in the final interview, "It was quite messy. We had a sloppy plan. We had to revise our data collection tools and lesson plans many times". Likewise, Yangzom wrote in her diary, "I think it was not swift. It was full of ups and downs because we were doing it for the first time". Yangzom recalled why two of their teaching strategies were ineffective, "We did not have an effective reinforcement strategy to encourage students to ask questions. The paper stars were just papers and Jimba was a bit strict". The teachers also pointed out the positive outcome of their project. Sangay said, "In the end, we found a new and effective teaching strategy". Yangzom highlighted the factors that constrained their efforts, "It is hard to give hundred percent due to our heavy workload, time shortage and heavy syllabus". Following this group reflection, the teachers showed interest in undertaking the second cycle. Sangay said, "We have a better understanding of the process now. We can do better in the next cycle. Although the teaching strategies were effective, we want to try out other strategies such as cooperative learning methods". Similarly, Yangzom suggested, "Now we have realised the importance of having a good plan. Next time we will spend more time on planning". This forward-looking view was an initial plan for the second cycle. However, the teachers could not carry out the second cycle due to time constraints.

5 Discussion

This study explored the action research process used by three Bhutanese secondary science teachers in a case study school to carry out their first action research using Kemmis and McTaggart's [15] model to enhance students' interaction in the ninth-grade Biology class. The study found that the teachers conducted multiple iterations, making the process messy as they took back-and-forth steps between the specific steps in each phase of the model. The iterative process occurred as the teachers undertook repeated steps of seeking clarification of the process, designing the data tools, modifying the plan, re-implementing the plan, collecting additional data, analysing the data, and reflecting on the results. This finding demonstrated the non-linear process of action research which is inconsistent with the neat and spiral process of Kemmis and McTaggart's [15] model used in Bhutan. It confirms Kemmis et al.'s [16] proposition that action research is rarely a neat process but involves the researcher moving back-and-forth between stages. The finding is also quite like the action research models developed by Calhoun [3] and Mills [25] that depict a back-and-forth movement between the phases. It also concurs with the findings of previous studies conducted by Cook [7] and Goodnough [13] examining teachers' enactment of action research and revealing the non-linearity of the process. Cook (7, p. 279) described the experience as entering the "messy area" of action research. The teachers in this study also found the multiple iterative and messy process challenging and expressed various emotions such as frustration, confusion, and uncertainty. Overwhelmed by the messiness, the teachers almost gave up in the *act* phase. Such findings were also revealed by Fitzgerald et al. [12] who recorded their frustrations and confusion as they experienced the messiness in carrying out action research on physical education. Furthermore, four teacher participants in Rust and Meyers' [34] study in the USA felt intimidated and anxious about the complexity of the action research process.

Despite the challenges, this study also found that the iterative and messy process benefited the three teacher participants in several ways. Multiple iterations helped the teachers to make progress through the process and eventually identify a teaching strategy that raised their students' classroom interaction. The teachers could also gain a better understanding of the issue they were exploring, devise a plan of action, refine the data collection tools, refine their teaching strategies, collect additional data, analyse the data, reflect on the results of the data analysis, and eventually identified the combination of group activity, questioning method, and reinforcement strategy as the most effective teaching strategy to raise student interaction. The teachers' interrogation of their classroom situation to create a pedagogical tool that raised students' interaction indicates the liberating function of action research [5, 15, 16]. Such pedagogical gains concur with Capobianco and Fieldman [4] and Laudonia et al.'s [19] claim that action research is an effective tool for science teachers to improve their teaching practices. It also supports Kijkuakul's [17] study that found Thai Science teachers' collaborative action research using Kemmis and McTaggart's [15] model resulted in teachers being able to shift their teaching practices from lecture method to experimentation method to meet the national science curriculum standards. It also confirms Lebak and Tinsley's [20] study in the USA which revealed three science teachers shifting from teacher-centred to student-centred teaching. Furthermore, the multiple iterations helped the teachers in this study to establish the methodological rigor of their action research by refining the data

tools and collecting additional data which aided in the proper assessment of the effects of the interactive teaching strategies they had implemented. This supports Cook's [7], Koshy's [18] and Feldman's [10] claim that multiple iteration leads to methodological rigour.

While the findings of this study and evidence from international literature show multiple iterations and mess as an inherent part of the action research, the MoE in Bhutan has not considered these ideas in the action research knowledge disseminated to teachers. The action research handbook developed by the REC [33] describes action research as neat cycles of *plan, act, observe* and *reflect* phases, which could lead teachers to develop a false impression of action research as a straightforward process. It could also cause teachers to misconstrue the back-tracking steps as a hindrance, non-progressive, undesirable, inappropriate and potentially develop a negative image of being incapable researchers. This might discourage Bhutanese Science teachers from taking up action research for their professional development. Furthermore, when writing an action research report, the linear process in the handbook might influence the teachers to conceal the messiness which is a valuable part of action research and simply write a tidied-up account of the process. Sharing action research through a candidly written report is important because others in the educational community are constantly seeking ways to improve their teaching practices [24]. The exclusion of mess might hide the key moments of action research where the researcher engaged in difficult thinking, the points where learning and unlearning took place and the creative parts that forge change in practice. The teacher participants in this study took creative steps such as redesigning the plan, redesigning the data tool and modifying the teaching strategies to improve students' classroom interaction. Such valuable accounts should be included in the report so that others in the education community can gain insight into a true account of how action research led to improving teaching practices and student learning. Considering the absence of multiple iterations, mess and teachers' continuous reflection, the action research handbook in Bhutan essentially requires a major revision to include these ideas. It needs to highlight that messiness and unsettling emotions are a part of action research and an indication of progress [7].

The other benefit of carrying out multiple iterations was that the science teachers were able to continuously reflect and address the challenges they faced in each iteration. The teachers' continuous reflection indicated that reflection was pervasive throughout the action research process and not the last phase of the process as shown in Kemmis and McTaggart's [15] model. The teachers' continuous reflection led to addressing the challenges of each step and the development of a teaching strategy to enhance their students' interaction, hence, enabling them to be reflective practitioners. This implies that action research offers an alternative to the existing externally driven, top-down and fragmented format of professional development in Bhutan offered through one-shot workshops. It enables teachers to take an insider stance, rather than objectively being an outsider, to inquire into their practice and classroom condition through critical self-reflection and take actions to create a just and rational situation to foster teaching and learning [5, 15, 16]. The finding offers confirmation of Antle's [1] and Burns' [2] view that multiple iterations allow teachers to engage in constant self-reflection to improve their practices or solve practical problems. Similar findings were also reported in Eilks and Markic's [9] study in Germany where Chemistry teachers developed reflective abilities through action research to change their teaching practices. However, the notion of continuous reflection has not been included in the action research handbook in Bhutan. The handbook describes reflection as a one-time process conducted in the final phase of Kemmis and McTaggart's [15] model. This could lead Bhutanese teachers to misunderstand reflection as a process conducted only in the final phase of action research. Hence, the revision of the action research handbook in Bhutan needs to consider the ubiquity of reflection in the four phases of Kemmis and McTaggart's [15] model and describe it as a process that occurs from the start until the end of action research and highlight its benefits.

While the inclusion of ideas such as multiple iterations, mess and continuous reflection would fill in the missing information in the action research handbook, conducting professional development programs would make teachers fully aware of these new ideas. This could be achieved through the initiative of the MoE and the teacher education colleges. Up until now, in-service, and pre-service teacher education programs on action research have educated teachers on the process of Kemmis and McTaggart's [15] model. This study suggests that the MoE and teacher education colleges incorporate the benefits of multiple iterations, messiness, and continuous reflection in action research professional development programs. The professional development programs need to emphasize that mess and multiple iterations are normal and inherent in action research and not a hindrance. Additionally, the notion of continuous reflection in conducting multiple iterations and its benefits in taking reflective action should also be emphasised. These efforts would support teachers to gain an adequate understanding of the process of conducting action research.

6 Conclusion

This study explored how three Bhutanese secondary science teachers conducted action research using Kemmis and McTaggart's [15] model to raise students' classroom interaction. Kemmis and McTaggart's [15] model is currently disseminated to teachers through an action research handbook. The study found that the teachers conducted a multi-iterative and messy process and engaged in continuous reflection to develop a teaching strategy to improve student interaction. The messy and multi-iterative processes were inconsistent with the neat and cyclical process of action research depicted by Kemmis and McTaggart's [15] model. The continuous reflection also did not concur with the depiction of reflection as a one-off phase at the end of each cycle in Kemmis and McTaggart's [15] model. The study suggests a necessity for creating awareness among Bhutanese teachers to embrace multiple iterations, mess, and continuous reflection as a part of action research by revising the handbook and conducting professional development programs. However, these findings emerged from only one action research cycle due to time constraints. This opens a scope for further research to observe the action research process over multiple cycles. Since Bhutan is a Buddhist country, cultural factors might have influenced the way teachers carried out the process of action research. Future studies could also explore the influence of cultural factors on the way Bhutanese teachers carry out action research.

Author contributions TR conceptualised and designed the study, collected the data, analysed the data, and wrote the manuscript. GK supervised the research process and reviewed the final research report.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval and consent to participate Approval for the study was sought from Monash University Human Research Ethics Committee (MUHREC), the Ministry of Education in Bhutan and the school leader of the case study school. Informed consent was sought from the participants.

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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