Secondary In-Service Mathematics Teachers' Self-Reported Teaching Practices and Their Views on Using Games in Teaching

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We report on findings from a study involving 15 secondary mathematics teachers from Fiji. The aim of the study is to describe teachers' current approaches to teaching probability and statistics; and to share their views on using game-based teaching approaches. We report briefly on the first stage of follow-up on one teacher who agreed to develop and implement a lesson. The findings suggest teachers use of concrete materials is limited to conducting simple demonstrations. In statistics, teachers reported using data derived from real life scenarios. Teachers also registered strong support for using game-based teaching. Lack of time was listed as the major inhibiting factor.

Probability and statistics is one of the strands in mathematics where students as well as teachers face a lot of difficulties (Batanero et al., 2004; Koparan, 2022; Leavy et al., 2013). One of the possible explanations for the challenges can be attributed to the need to think and reason statistically. This is because probability and statistics are areas of mathematics that rely heavily on our day-to-day activities, including making predictions about uncertain events related to our lives, such as predicting the weather or the winner of a sporting match. A related reason for such difficulty for students could be linked to the traditional chalk-board teaching approaches used to teach the topic (Koparan, 2022).

One of the ways to build a deeper understanding of probability and statistical literacy is through engaging learners in game-based teaching scenarios. As Koparan (2022) points out, games, including technology-based games, "has become one of the interests of the students" (p. 2333). Koparan (2022) adds that reducing the authoritarian teaching methods and offering more opportunities for active learning, where learners can discuss, visualise, estimate, control and experiment with probability and statistics situations can help with enhancing probability and statistics literacy. In light of this, there is an increasing need for additional research on teachers because most teachers teach probability and statistics like other mathematical strands with a heavy focus on procedures alone rather than on probabilistic or statistical reasoning (Koparan, 2022). There is also a need to investigate further into teachers' beliefs and attitudes as these can easily be transmitted into their actions (Batanero & Álvarez-Arroyo, 2024; Koparan, 2022).

In this study, we report findings on a small sample of Fijian secondary mathematics teachers' views and experiences about teaching probability and statistics. We also report on their perspectives about a game-based probability teaching sequence that they were exposed to during the study, including the perceived challenges and opportunities for including such games-based approaches in their actual teaching. We report on one of our participants' desire to plan and implement one such lesson in her classroom. The research questions addressed in this study are: What are Fijian secondary mathematics teachers' views and their self-reported practices about teaching probability and statistics? To what extent do they find the probability teaching sequence useful? An additional research question to which we offer partial answer is: How well does one participant plan a lesson on using a game-based strategy? After presenting the theoretical framework of the study, a literature review and the study's context and

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methodology are presented. This is followed by the main findings of the study. A short discussion and conclusion sum up this paper.

Theoretical Orientation of the Study

In this study, we used the socio-cultural learning theory. According to Cobb (2007), the socio-cultural theory seeks to "investigate the participation of the *individual-in-cultural-practice*" (p. 22, emphasis in original). According to this view, a learner learns based on his or her interactions, and using appropriate tools, with an adult or a more learned peer. This enables learning to move towards independent learning, a movement from the "plane of social interaction" towards the "plane of individual thought" (Cobb, 2007, p. 22). This notion of learning rests on the idea of the zone of proximal development (ZPD) which refers to the level of potential development which a learner is able to move to under the guidance of a more knowledgeable person (Heritage, 2013). Following Vygotsky and Cole (1978), the socio-cultural theorist sees cognition as "extending out into the world and as being inherently social" (Cobb, 2007, p. 23).

In this study, we focus on secondary mathematics teachers as learners. A socio-cultural view of adult learning is relevant because we propose a new design-based teaching approach to our participants after gaining an understanding of their current teaching practices. We then look at how or what our participants have learnt through our intervention. We also explore the limitations and opportunities our participants see in this new teaching approach. While socio-cultural theorists see learning as deeply rooted in participants' established classroom practices, these practices are subject to transformation and subject to potential new learnings that our participants might gather from our intervention. In our follow-up phase, we hope to continue working with some participants in future. In this way, the current study paves the way for establishing a community of practice by bringing individuals together to work on new instructional designs. According to Koparan (2022), it is important to support teachers to create different learning environments for their learners.

Literature Review

Research on teaching probability and statistics points out many unique challenges that teachers and students encounter. For example, findings from studies on pre-service mathematics teachers show that pre-service mathematics teachers find probability and statistics as difficult. A study by Leavy et al. (2013) for example noted how pre-service teachers found probability and statistics reasoning to be surrounded with uncertainties in comparison to other areas of mainstream mathematics. Similar findings have been noted in studies like Batanero et al., (2004) and Koparan (2019). Studies such as Koparan (2022) point out that students find probability as a difficult topic.

The literature also points out some of the effective ways in which teachers could overcome the challenges of teaching probability and statistics. One of the notable approaches seems to be the use of challenging teaching scenarios such as games (Batanero et al., 2004; Koparan, 2019, 2022; Sharma et al., 2021). In probability teaching, game-based learning involves situations where learners engage in a play-like scenario involving some aspects of probability. For example, the *stone-paper-scissors* is a common game that could be used to teach certain aspects of probability. Research shows multiple benefits of teaching using game-based strategies, such as improved student motivation and ability to work in groups (Koparan, 2022). Research on the use of such challenging game-based scenarios is generally focused on pre-service teachers. For example, one recent study involving 94 prospective mathematics teachers involving a quasi-experimental research design with pre-and-post tests showed that there was a significant difference in achievement and attitudes of prospective teachers in the experimental group who were exposed to a variety of materials such as worksheets, concrete materials, games and

simulations. Koparan (2022) concluded probabilistic and statistical reasoning can be improved using activities "that push students to conduct research, make predictions, think, assess and to explain the logic they observe" (p. 2333). Similarly, a review on literature on teaching and learning probability noted that activities such as modelling can help teachers develop their content and pedagogical content knowledge (Batanero & Álvarez-Arroyo, 2024). In summary, there is tremendous support present in the existing research literature on using a variety of activities, including game-based scenarios, although most of these studies were focused on pre-service teachers (Dayal & Sharma, 2021; Dayal & Sharma, 2020; Kazak & Pratt, 2017).

In one study involving a small sample of six secondary in-service mathematics teachers, Sánchez (2002) reports findings about teachers' views on a simulation software for developing probability concepts. The study's participants reported having a better understanding of probability concepts, recognising simulations as a useful technique to solving probability problems. However, the participants could not suggest situations closer to students' reality where simulations could be applied. From a Pacific Islands context, Dayal and Sharma (2020) report on how pre-service teachers were unable to make correct predictions on a game-based activity. The study noted that after doing the activity in full, pre-service teachers reported having a deeper understanding of the game-based teaching sequence. This study, while based in a Pacific Islands context, hopes to add to our understanding of how practicing mathematics teachers teach probability and statistics as well as what they feel about using game-based teaching approaches given that there are relatively fewer studies reported on in-service mathematics teachers.

Context and Methodology

Context

This study was part of a larger study carried out with mathematics teachers from five schools in the Western part of Fiji. The larger study unfolded in three phases, and involved 15 secondary mathematics teachers. Phase one involved one-to-one interviews with teachers. In phase two, the teachers took part in a two-hour workshop where they were exposed to the probability teaching sequence. Phase three involved post-workshop reflections. In the Fijian mathematics curriculum, the probability and statistics strand is known as Chance and Data. Chance and Data strand appears right from Year 1 curriculum. As early as Year 1, children are expected to discuss the likelihood or chances in an event, and draw and show simple data using a bar graph. Making predictions is one process that appears strongly from primary year levels. For example, in the Year 1 Numeracy curriculum, one of the activities requires students to throw stone into a circle made on the ground. Students first make predictions on how many stones will land inside the circle, then carry out the experiment and record data on their predicted and actual outcomes of the trials (Ministry of Education, 2017). In secondary schools, Chance and Data is offered from Years 10 to 13. Similar to primary school curriculum, teachers are expected to teach both content and processes such as statistical or probabilistic reasoning. For example, at Year 10, students are expected to demonstrate probability experiments by using a coin, die and pack of cards and list the respective outcome (Ministry of Education, 2014).

Methodology

We adopted a design-based research approach whereby our participant teachers were involved in a cyclic process involving action and reflection (Cobb & McClain, 2004). In this study, we report on phase one and phase three findings. In phase one, through one-to-one interviews, we explored participants' views about teaching and their preferred styles of teaching. We posed questions such as: *How do you normally teach this strand? Do you ever use any kind of game-based teaching?* In phase two, we conducted a two-hour professional learning workshop with the 15 participants. In this session, our participants were taken through

the probability teaching sequence which involved a scenario where two players play a dice rolling game. Upon each throw, the difference between the two dice is noted. If the difference is 0, 1, or 2, player A wins. If the difference of the scores is 3, 4, or 5, player B wins. At the start of the probability teaching sequence, our participants were asked to predict whether the game was fair or not. Later they played the games in groups and calculated the experimental probabilities and reconciled these with the theoretical probabilities. After the probability teaching sequence workshop, all participants took part in written reflections that focused on questions: Can you share your views about this activity? Would you use this type of teaching sequence in your teaching? What would be some of the benefits and challenges? Consistent with design-based research, we included a follow-up phase where we requested our participants to develop lesson plans that could be used in their actual classrooms.

All the interviews were audio recorded and we conducted a thematic analysis on all interviews and written reflections (Braun, et al., 2022). For example, in analysing participants self-reported teaching practices we used categories such as 'no games used', "use of concrete materials or real-life data/activities' and 'use of games' and added participant's examples to the latter two categories. Similarly, in analysing their post-workshop reflections, we looked at teaching areas they had identified, as well as their anticipated challenges and opportunities. There were seven male and eight female participants in this study. Their educational qualifications ranged from a Diploma in Education (one participant), a bachelor of education with mathematics as one major (12 participants) and a postgraduate qualification in mathematics or education (two participants). On average, the participants had 11.5 years of teaching experience.

Findings

The first part of this section presents participants' views and experiences on teaching probability and statistics. The next sub-section presents participants' reflections and the teaching ideas they could derive from the probability teaching sequence. Finally, we present findings on how one participant developed a lesson plan based on a game scenario.

Participants' Views and Experiences on Teaching

All fifteen participants agreed that the teaching probability and statistics required teachers to cover both theoretical and practical dimensions of the subject, with all agreeing that using practical activities was better method because "when they do experiments on their own, they understand what is happening" (Hafiza's interview). Also, some participants strongly agreed that probability and statistics is one area of mathematics that rests heavily of daily activities. They mentioned daily activities such as sporting activities, weather patterns, or winning lotteries. Most of the participants said that they include practical aspects in their teaching although this was limited to certain activities, topics and year levels. Participants were able to share more examples of practical activities under the Statistics strand. Almost every participant shared data gathering activities which would lead to students creating different representations of the data. The examples teachers gave focused on students' real-life scenarios such as measuring height or weight (Anit's interview), tracking attendance and punctuality records of their class or school (Ratu's interview), or the modes of transport for students in a class (Sen's interview). However, all the participants agreed that the amount of time spent on such activities was small in comparison to the time used on traditional text book-based teaching methods that involved giving notes and examples and lots of questions to solve. Some participants, especially those teaching examination classes agreed to using lot of past year examination papers (Hafiza's interview). Three participants said they would use YouTube videos occasionally to demonstrate some concepts, while one participant said that she encouraged students to prepare PowerPoint presentations and engaged students in peer teaching.

Under the probability strand, all the participants said they used concrete objects such as coins, dice and playing cards, although teachers from two particular schools said they did not use these because of religious restrictions placed by their school on using any form of gaming materials in their teaching. Some teachers from the two schools said that they used coins, dice and cards only after seeking permission from their school principals. Almost every participant gave an example that made use of coins, dice or playing cards. For example, use of coins to conduct experiments or trials to find out the frequency of certain events (Ela, Rose, Ratu, Kaju's interview) or using a die to play a game of snakes and ladders (Kaju & Sheni's interview) or using a deck of cards (Navi's interview) were some of the examples given by the participants. While some of the participants could link the activities to student learning outcomes in probability such as finding the sample space when a coin or a die is tossed a given number of times, a few participants could not link the activities to any student learning outcomes. For instance, Sheni stated that she used coins and dice "just to give them a feel of it" when she began her lessons. Others such as Navi or Atish stated that coins or dice were used "for demonstrations". Only one participant explicitly said that she did not use any coins or dice for demonstrations simply because she was pressed for time to cover the syllabus (Hafiza's interview).

While all (except Hafiza) made use of simple activities involving concrete objects described above, 13 out of the 15 participants said they did not use any kind of games in their teaching. Reasons provided for not using games was often linked to the syllabi. In other words, the participants said that there were too many concepts to teach and thus a lack of time to cater for any kinds of games-based teaching. They also stated that the current curriculum did not support the use of games as only certain examples (such as conducting trials using two coins) are given in the curriculum and the textbooks. In other words, as the current curriculum did not support the use of games-based teaching approaches. As one participant stated, "the current curriculum is outdated, the text-book is way outdated" (Navi's interview). Another participant said that she "didn't see any games" in the curriculum (Hafiza's interview). For some other participants such as Jone and Mata, they said they developed their own games or activities. Jone and Mata were the only two participants who stated they had used some type of game-based scenarios in their teaching.

For example, Mata mentioned using crossword puzzles in her probability teaching but her description was not explicit. Similarly, she gave another example of involving students in throwing a pair of dice and adding the sum of the outcomes on each throw. According to Mata's description, the game would be played in groups of four and students roll a pair of die and add the outcomes on each throw. According to her, "if the group throws a "one", their total goes back to zero. The group that gets the highest total sum wins". When probed further on what learning outcomes this game would lead to, she explained that "they learn about the chances of getting a one". Jone stated that he used a similar game, but the students would calculate the difference of throwing a pair or die. He explained that "each group was given a paper and two die and they compared the outcomes for each roll of the two dice. We compared what is the difference of the two". When asked to link it to learning outcomes, Jone stated that "they would learn about trials and sample space". He argued that students would get a better understanding of these terminologies (such as a trial, event or sample space) if they were exposed to playing such games. All the participants took part in the probability teaching sequence after their initial interviews.

Participants' Reflections on the Probability Teaching Sequence

All the participants found the probability teaching sequence workshop a rewarding experience. It made participants reflect on their own probability knowledge as well as pedagogical knowledge. In other words, the participants reflected on how it made them aware

of their own understanding of such games-based probability events. One of the reasons stated was that the workshop made participants 'actually see what happens' after making an initial prediction (Hafiza's reflection). For another participant, it was a 'good way to relate theory to practical' (Jone's reflection). One participant realised that the importance of understanding the context of the game as he mentioned that "catch was in the rule of the game itself (Navi's reflection). As another participant stated, 'predictions do not mean it will always be correct' (Sen's reflection). All the participants (except Jone) made predictions that were incorrect. In their reflections, some of the participants expressed how the activity them aware of the fairness of the game only after they had a chance to play the game.

Reflections on Probability Teaching Ideas

All the participants were able to list at least one teaching idea. Teaching ideas that appeared more frequently had to do with the use of coins or a deck of cards to conduct trials and to find out probabilities of simple events such as a head or tail. In addition to this, only a few participants noted other teaching areas such as sample space or checking on fair and bias games. Only one participant listed relating probability to statistics by using tally, frequency and other ways of recording data. However, two of the participants listed teaching areas that seemed incomplete. For example, one participant gave example of a volleyball game context and said students could calculate chances of hitting the volleyball (Sen's reflection). All the participants insisted the activity was useful because it will help students to make predictions, play games, and find the actual outcomes for themselves. It would help children get on hands on activities and develop their probability thinking. As one participant wrote, while both the dice are fair, the event was not fair. Carrying such experiments during class will "help students to learn that even though the die is fair and the probability of each throw is same, the chances of achieving each outcome was different." (Navi's reflection). Apart from these perceived advantages, one participant noted how the activity could involve everyone in the class (Rose's reflection). For example, some could play, some would record and all could discuss the outcomes. For two other participants, this activity would generate student interest in probability and statistics (Atish's and Mata's reflection).

When asked about some of the perceived challenges, lack of time came out as the main challenge. Many participants thought the activity was time consuming and may not be possible in one teaching period. Some participants saw large class size as a potential issue. Apart from time factor, two of the participants felt that the activity could be confusing to some students because it is a contradicting experiment about fairness (Kafi and Mata's reflection). Another teacher added that 'outcome is fair but difference in outcome is not fair' and this could be a contradictory point for some students to understand (Mata's reflection).

Developing and Implementing a Game-Based Lesson—A Follow-Up with One Participant

At the end of the workshop, we invited the participants to develop lesson plans on any teaching ideas that they derived from the workshop which they would likely use in their actual classroom teaching. At the time of writing, we had email correspondence from two teachers who are from the same school. Regrettably, one of the participants later resigned from teaching. The other participant, Rose, had emailed us her teaching ideas in the form of a lesson plan for a Year 10 probability lesson. While her initial lesson plan is only one page long resembling the typical lesson planning style in Fijian schools, the intended lesson goals are "Compute the probability from an experiment consisting of equally likely outcomes". Her description of student's activity contained only a short description on "Participate in group activity, throwing a pair of dice, and taking note of the results". We are currently working with her on how to add more details on student's activity section of her lesson plan.

Discussion and Conclusion

The aim of the study reported in this paper was to explore teachers' self-reported teaching strategies and their views on a game-based teaching activity. While our sample size was small, this study makes a useful contribution in terms of involving secondary practising teachers. As noted in the literature, there are limited studies involving secondary practising teachers (Batanero & Álvarez-Arroyo, 2024). With respect to our first research question, the study's findings suggest that all the participants agreed that probability and statistics require more activity-based teaching rather than chalk-and-board type teaching. In terms of their current teaching strategies and the extent of use of game-based activities, only two participants said they had used games in their teaching. The rest of the participants stated using common artefacts such as coin or die, but mainly for simple demonstrations. In teaching statistics, more participants could provide examples of using real-life examples and data derived from real-life scenarios. One of the possible reasons for the use of more real-life examples and data in the statistics strand could be related to the curriculum resources, such as textbooks having worked examples. The same cannot be said for the probability strand because, as many of our participants suggested, there were some concerns at the lack of support from the curriculum itself on the use of activity-based teaching approaches in probability. For example, some participants mentioned lack of examples or activities listed in the syllabi or the text book. We note that the Fijian Year 10 Probability Syllabi only mentions use of coins or dice for simple demonstrations (Ministry of Education, 2014). Also, teachers in Fiji generally have to cover the syllabus in preparation for external examinations. This reason was shared by some of the research participants. However, not all year levels have to take an external examination at the end of that academic year. There may be other reasons that prevent teachers from using game-based teaching strategies especially in the non-examination classes. For example, an added reason for a lack of involvement in game-based teaching could be attributed to a lack of understanding on how to integrate games in the lessons. Previous studies such as Dayal and Sharma (2020) and Koparan (2022) lend support for such arguments.

With respect to participants' views on the probability teaching sequence, there was overwhelming support about the value of using such game-based activities. Reasons provided by the participants included 'better student involvement' and 'improved student motivation'. These findings are consistent with the findings about the benefits of game-based teaching approaches in the literature (Dayal & Sharma, 2021; Koparan, 2022). In terms of the anticipated challenges, the findings indicated that lack of time would prevent the participants from using game-based teaching approaches. We speculate that teachers will need more support in creating and implementing lessons that make use of a wide range of activities such as games. This study has provided us with some initial insights on our first stage of follow-up phase where only two participants out of the 15 communicated to us, via email, their intentions of planning and using a game-based lesson.

We hope to work with one participant in the follow-up phase. Our participant has submitted her first lesson plan. While the proposed lesson's learning outcome seemed appropriate for Year 10, we have provided some feedback on how to include clearer steps for a deeper level of student engagement in the proposed lesson. From a socio-cultural perspective, this is encouraging since this collaboration gives some support to the claim that teachers can gradually adopt activity-based teaching when given appropriate support. Researchers need to continue to work together with teachers to find ways to help teachers develop probabilistic and statistical thinking.

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