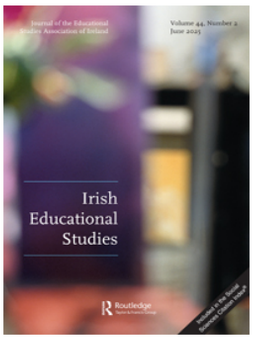

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Unpacking the motivational variables which impact engagement in Lesson Study: Mathematics teaching self-efficacy and attitudes towards self-development

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ABSTRACT

Lesson study has received significant attention as a model of professional development among mathematics teachers. Evidence highlights its effectiveness in improving pedagogical practices and student learning, however, less is known about the predispositions which may encourage teachers' participation in Lesson Study or the impact of participation on teachers' attitudes. Such findings are relevant considering the voluntary context of teachers' participation in professional development in Ireland.

This research investigates the motivational variables which impact teachers' participation in Lesson Study, specifically their self-efficacy in teaching mathematics for conceptual understanding and their attitudes towards self-development in Lesson Study. Post-primary mathematics teachers ($N = 64$), spanning various levels of experience in Lesson Study, completed a survey using a set of pre-validated scales. Findings indicate that teachers' mathematics teaching self-efficacy is a significant predictor of their participation in Lesson Study. Furthermore, the research finds that teachers' familiarity with Lesson Study impacts the likelihood of their participation in this model of teacher education.

These findings build upon previous knowledge in this field and demonstrate the significance of teaching self-efficacy as a presage variable for developing a positive disposition towards Lesson Study. The paper discusses the implications of these findings for teacher education in Ireland.

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Lesson study; teaching self-efficacy; professional development, teacher motivation

Introduction

Lesson Study is a model of teacher professional development which originated in Japan over a century ago (Takahashi 2014). It is based on the premise of teachers collaboratively researching their practice to improve their students' learning and has been growing in popularity worldwide as a way of supporting teachers to develop their pedagogical practices (Stigler and Hiebert 2016). While the outline of the Lesson Study follows several

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Table 1. Phases of lesson study within one cycle (Clivaz and Ni Shuilleabhain 2019).

0	Consider issues and formulate general goals
1	Study curriculum and formulate content specific goals
2	Collaboratively plan a research lesson (select or revise content, consider elements of the research lesson, detail the conduction of the lesson etc.)
3	One member of the group conducts the research lesson, with other members of the group observing and recording data on student learning
4	Reflect on the data from the research lesson and document the lesson study cycle

phases within a cycle (see Table 1), it should not be considered as a formulaic procedure or prescribed routine but rather forms a set of principles that can frame an approach to collaborative professional learning.

By participating in Lesson Study teachers play an active role in researching, designing, implementing, recording and reflecting on the content and context of a lesson (Jhang 2020; Lewis and Perry 2017). Through these phases of Lesson Study, working and conversing with colleagues, teachers bring the complexities of teaching to a collaborative setting outside the classroom, considering, discussing and deconstructing their professional and pedagogical thinking and decision-making (Kager et al. 2022; Takahashi and McDougal 2016).

The dialogic space provided to teachers within the phases of the Lesson Study cycle gives rise to knowledge-building exchanges (Ni Shuilleabhain 2016; Warwick et al. 2016) and provides teachers with a setting within which to trial new pedagogical practices (Hourigan and Leavy 2022; Ni Shuilleabhain and Seery 2018; Schipper et al. 2018). Research has demonstrated that participating in Lesson Study can focus teachers' attention on student thinking (Amador and Carter 2018) and build teachers' skills in anticipating their own and students' responses throughout a lesson, thereby facilitating more deliberate decision making within the complex environment of the classroom (Widjaja et al. 2019). Lesson Study has been shown to have the capacity to improve teachers' content and pedagogical content knowledge, and to positively impact on students' classroom experiences and learning outcomes (Lewis and Perry 2017; Ni Shuilleabhain 2016). Participating in Lesson Study has also been demonstrated to develop teacher confidence (Rock and Wilson 2005), teacher self-efficacy (Schipper et al. 2018) and teacher community (Lewanowski-Breen, Ni Shuilleabhain, and Meehan 2021).

The implementation of Lesson Study is not always straightforward, particularly in countries where it is not a culturally established form of teacher education (Stigler and Hiebert 2016). Teachers have often demonstrated misconceptions in their first experiences of it, which may impact their enthusiasm for participation (Fujii 2014; Nguyen and Tran 2022). For teachers who are not confident in their content knowledge or teaching experience, for newly qualified or out-of-field teachers, there can be a reticence in being involved for fear of being seen as incompetent by their more experienced colleagues (Fernandez 2002; Lewis, Perry, and Hurd 2009; Puchner and Taylor 2006). While Lesson Study is a model of teacher education built upon the principles of teacher autonomy, the observation of peers' teaching practices may be conceptualised by some teachers as an undesirable notion (Reilly 2017). Once teachers are engaged, however, research demonstrates that they begin to enjoy the opportunity to gain feedback on their teaching and pedagogy (Widjaja et al., 2019). Furthermore, teachers begin to view the learning of their less experienced colleagues as part of a shared responsibility

within the Lesson Study process (Lewanowski-Breen, Ni Shuilleabhain, and Meehan 2021; Lewis, Perry, and Hurd 2009). It is important, therefore, that practitioners of Lesson Study understand fully the motivational factors which might impact a teacher's decision to participate (Jhang 2020). This is particularly relevant in the Irish context where a teacher's participation in professional development remains voluntary and without formal recognition (McMillan, McConnell, and O'Sullivan 2014). Considering the national contexts of curriculum reform and the need for associated teacher education, in this research we hope to contribute to the literature investigating the influence of teacher self-efficacy and attitudes towards Lesson Study on teachers' participation.

Lesson study in Ireland

While participation in collaborative teacher communities is increasingly realised as a key dimension of teacher professionalism (Vescio, Ross, and Adams 2008), professional development in Ireland has predominantly been in the form of exposition from an 'expert' facilitator (Sugrue 2011). Teachers have increasingly voiced their desire for more engaging, impactful forms of teacher education, expressly emphasising the need for opportunities to discuss teaching and learning with colleagues (Johnson, Freemyer, and Fitzmaurice 2019; Neururer and Ni Shuilleabhain 2022; White, Johnson, and Goos 2021). School-based collaborative professional practice has been highlighted in policies related to pre-service and in-service teacher education (Moynihan and O'Donovan 2022) with, for example, school self-evaluation guidelines emphasising opportunities for teachers to participate in individual and collaborative critical reflections on their practice (DES, 2022). The STEM Education Policy Statement 2017–2026 emphasises collaborative professional working within schools (DES, 2017). Furthermore, the Cosán framework, a national policy for teacher learning, recognises teachers as autonomous and responsible professionals who can prioritise professional learning that benefits them and their pupils (Teaching Council 2018).

Since 2014 Lesson Study has become a prominent model for teachers' learning incorporated by the state's Professional Development Service for Teachers (PDST) in their post-primary teacher support model and, later, with primary teachers. An average of 150 post-primary teachers participated in Lesson Study each year until 2019 when initiatives were postponed due to COVID-19 restrictions (personal communication with PDST). Outside of national teacher education structures, Lesson Study has been incorporated in initial teacher education across primary and post-primary levels (e.g. Corcoran 2011; Ni Shuilleabhain and Bjuland 2019). Furthermore, the literature provides examples of in-service primary and post-primary teachers participating in Lesson Study with researchers both in-person and online (e.g. Holden 2023; Hourigan and Leavy 2022; Ni Shuilleabhain and Seery 2018). Research has evidenced success in terms of teacher learning and student outcomes in relation to the implementation of Lesson Study in Ireland (e.g. Curran 2020; Hourigan and Leavy 2022; Ni Shuilleabhain and Seery 2018).

In the context of this research, it is also important to consider reforms which are underway in national mathematics curricula. At the primary level, a new mathematics specification is under consultation and due to be published in the near future. At the post-primary level, the curriculum has undergone immense reform in the past decade,

with a move from a prevalence of didactic and procedural approaches to teaching and learning towards approaches focused on developing conceptual understanding and problem solving (Prendergast and Treacy 2018). These shifts have resulted in a necessity for significant professional development for teachers of mathematics, who are required to conceive of new approaches and knowledge to effectively teach for student understanding (Oldham and Prendergast 2019). Johnson, Freemyer, and Fitzmaurice (2019) report that despite the new post-primary curriculum being implemented in 2012, mathematics teachers feel they have not received appropriate support in this area. In order to support teachers in enacting reform approaches, they require opportunities to engage in collaborative, practice-oriented experiences like Lesson Study that occur over an extended time-period and are targeted towards school-based actions (Hourigan and Leavy 2022; Ni Shuilleabhain and Seery 2018; Takahashi and McDougal 2016). Given the popularity of this model, therefore, across primary and post-primary education, it is important to consider teachers' attitudes towards Lesson Study and to investigate factors which might influence their decisions to participate in it within their schools.

Investigating motivational factors determining participation in Lesson Study

While there is wealth of literature establishing potential outcomes and implementation of Lesson Study, little is yet known about the factors which might motivate teachers to participate in Lesson Study. Such research is merited, however, as studies have emphasised the voluntary participation of teachers in Lesson Study as a key element of successful enactment (Ni Shuilleabhain and Seery 2018; Seleznyov 2018). In his research conducted with post-primary teachers in Taiwan, Jhang (2020) investigated factors determining teachers' engagement with Lesson Study. The research found that teachers' attitudes towards Lesson Study, specifically their attitudes towards self-development in Lesson Study, predicted their rate of completion of a full cycle (Jhang 2020). Additionally, the research found that a teacher's perceived competence (described further below) predicted their participation in Lesson Study (ibid). These results point to the motivational elements which determine teachers' participation in Lesson Study. Jhang's (2020) research did not indicate, however, whether these constructs motivated the uptake of Lesson Study initially.

Jhang (2020) defines a teacher's perceived competence as comprising various traits such as a strong knowledge base and a clear understanding of one's role. It has been argued, however, that a teacher's perceived competence relates more to their affective beliefs about their abilities rather than their knowledge (Hughes, Galbraith, and White 2011). Considering the factors demonstrated to negatively impact teachers' participation in Lesson Study (Fernandez 2002; Lewis, Perry, and Hurd 2009; Puchner and Taylor 2006), it may be important to focus how such affective beliefs might impact teachers' participation. Deci et al. (1991) suggest that a teacher's belief in their own ability to perform a task is correlated to the level of intrinsic motivation they have in an area (Fokkens-Bruinsma and Canrinus 2014) and, subsequently, related to their attitudes towards and use of evidence-based practice (Bedel 2016; Georgiou et al. 2020). McMillan, McConnell, and O'Sullivan (2014), in their model of motivation for teachers to engage in professional development, also outline how affective beliefs as intrinsic motivators

can impact on teachers' participation in professional learning. This model additionally considers how interpersonal relations, as contingent and tangential motivators (i.e. whether participation is compulsory or voluntary), impact teachers' decisions to engage in professional learning (McMillan, McConnell, and O'Sullivan 2014).

Self-efficacy, a belief which spans both the individual and social domains (Rodgers et al. 2014), may well be a worthy focus in investigating teachers' motivations to take part in Lesson Study. Friedman and Kass (2002) state that:

> Teacher self-efficacy is the teacher's perception of his or her ability to (a) perform required professional tasks and to regulate relations involved in the process of teaching and educating students (classroom efficacy), and (b) perform organizational tasks, become part of the organization and its political and social processes. (ibid, p.684)

This definition considers school and classroom context, as well as relationships among teachers, which is particularly relevant within the collaborative context of Lesson Study. Ledinez Munoz et al. (2023) demonstrated that participation in Lesson Study can result in the development of participants' self-efficacy, but little is known of the role of self-efficacy in teachers' decision-making to engage in this model of professional development.

Teaching self-efficacy can be predictive of teachers' overall engagement in their work, their sense of job satisfaction and their students' learning (Daumiller et al. 2021; Lipscomb et al. 2022). Teaching self-efficacy has also been shown to impact teachers' use of innovative teaching approaches (Zainal and Mohd Matore 2021).

For mathematics teachers, success in implementing reform and incorporating new teaching approaches can depend on their teaching self-efficacy . Teachers' perceptions of their own ability to formulate, represent and solve mathematical problems impact their capacity to trial new pedagogical practices (Riggs et al. 2018;). Mathematics teaching self-efficacy, which is based on teachers' belief in their ability to trial new mathematical practices and emphasise conceptual understanding, can impact a teacher's capacity to enact reform in their classrooms (Riggs et al. 2018).

Teaching self-efficacy has been demonstrated to significantly influence teachers' engagement in professional development (Li et al. 2022; McMillan, McConnell, and O'Sullivan 2014; Zhang, Admiraal, and Saab 2021). Low levels of self-efficacy have been demonstrated to impede teachers' participation in professional development, as observed by Gümüş and Bellibaş (2021) for newly qualified teachers. Little is understood, however, of the impact of teachers' self-efficacy on their willingness to participate in Lesson Study.

Present research

In this research, we use McMillan, McConnell, and O'Sullivan's (2014) model of motivation to participate in professional learning to examine the intrinsic factors of mathematics teachers' teaching self-efficacy and attitudes towards Lesson Study and examine these in relation to their participation rates in Lesson Study cycles.

Whereas Jhang (2020) determined predictive relationships between attitudes towards Lesson Study, perceived competence, and completion rates of a cycle, we aim to offer a more nuanced examination of how these factors may relate to participation rates,

focusing on mathematics teaching self-efficacy as a more clearly defined motivational factor. In the first instance, we aim to test Jhang's (2020) empirical relationship between attitudes towards self-development in Lesson Study and participation rates with a sample of practicing mathematics teachers. This will allow us to determine the nature of this relationship in the Irish context. Therefore, our first hypothesis states that: *Among a sample of practicing post-primary mathematics teachers, attitudes towards self-development in Lesson Study will predict participation rates in Lesson Study*.

Given the current introductory status of Lesson Study in Ireland, in this research, we include teachers who have not yet engaged in Lesson Study. However, given the potential for misconceptions in participants unfamiliar with Lesson Study (Fujii 2014; Nguyen and Tran 2022), it would be unreliable to rely solely on a measure of attitudes towards Lesson Study. As outlined above, we argue that teaching self-efficacy, as a motivational variable, aligns more coherently with the expected outcomes of participating in Lesson Study than perceived competence. We further refine this focus on self-efficacy to specifically relate to mathematics teaching in the context of curriculum reform (Riggs et al. 2018). We adopt a working definition of mathematics teaching self-efficacy as a teacher's self-perception of their own ability to teach effectively to promote their students' conceptual understanding of mathematical content and knowledge. Self-efficacy is an established predictor of teachers' attitudes across many domains, such as attitudes towards inclusion (Savolainen, Malinen, and Schwab 2022) and attitudes towards ICT usage (Pozas and Letzel 2021). Building on the work of Jhang (2020) and previous works on self-efficacy, we propose to examine the relationship between the variables of attitudes towards self-development in Lesson study and participation rates in Lesson Study, with the potential mediator of mathematics teaching self-efficacy. Our second hypothesis therefore proposes that: *mathematics teaching self-efficacy will be related to attitudes towards self-development in Lesson Study and mediate the relationship between teachers' attitudes towards self-development in Lesson Study and their participation in Lesson Study*.

Our hypothetical model to be tested is illustrated in Figure 1.

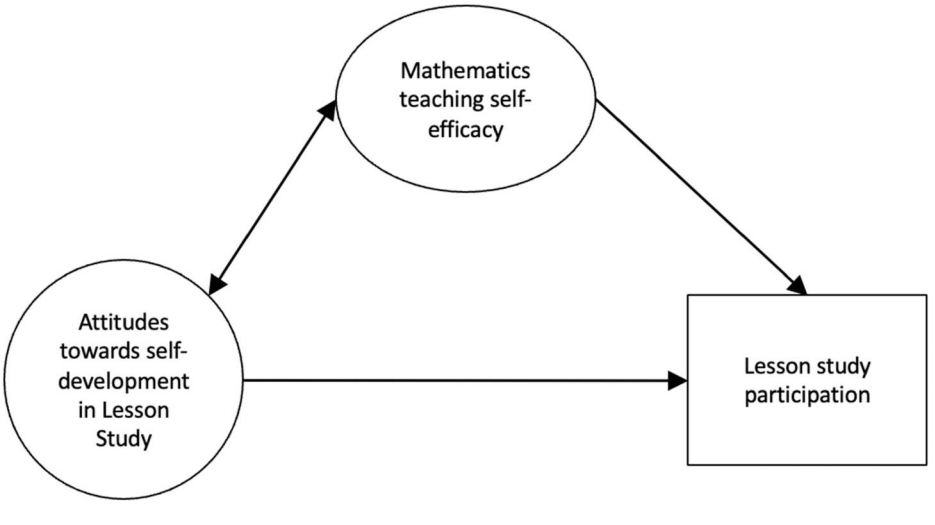

Figure 1. Hypothesised model of key study variables.

Method

To examine the relationship in Figure 1 a survey approach was adopted in order to access the broader population of post-primary mathematics teachers currently teaching in the Irish post-primary system. To capture evidence of the core latent variables of interest, i.e. mathematics teaching self-efficacy and attitudes towards self-development in Lesson Study, scales (described below) were chosen based on relevant research literature and our hypothesised model.

Participants

As the context for our research concerned mathematics education in the Irish post-primary context, a random volunteer sample of mathematics teachers was chosen. Core inclusion criteria included an appropriate qualification to teach post-primary mathematics in the Republic of Ireland. The survey was distributed online, hosted on Microsoft Forms, and advertised using a targeted recruitment drive on appropriate social media platforms, through mathematics teachers' associations and via email contact with schools, who were asked to circulate to mathematics teachers in their school communities. In line with ethical requirements surrounding voluntary participation, informed consent was collected during the first stage of the electronic survey.

To determine the sample size required to obtain sufficient power for later statistical analyses of the data, an *a priori* power calculation was performed. This was conducted using the 'pwr' package (Chamely 2020) in R (R core team, 2022). Using a post-hoc multiple regression model as the basis for the analytic approach with 2 predictors, a power level of 0.8 and a small effect size (0.15), a sample size of N = 64 was calculated.

In total, we received exactly 64 respondents (Mean age = 36.5 years, SD = 10.2 years) who met the inclusion criteria, with 18 males and 46 females. Teaching experiences of respondents (Mean = 13.3 years, SD = 9.6), ranged from a minimum value of 1 year and a maximum of 42 years. 46 of the teachers had previously participated in Lesson Study. This captured an adequate representation of mathematics teachers given the range of years of experience and power calculation.

Measures

Pre-validated scales were utilised to ensure suitable robustness, reliability and representation of the factors of interest. All scales in the study use a 5-point Likert format ranging from 'strongly disagree' to 'strongly agree'. Scoring procedures follow original study guidelines referenced herein.

Attitudes towards self-development in lesson study

To measure attitudes towards self-development in Lesson Study, we adopted the instrument utilised by Jhang (2020). The 'Attitude towards Lesson Study' scale is composed of 12 items assessing the purpose, benefits, impact on teaching and impact on student performance through Lesson Study (e.g. 'Lesson Study provides information about how to improve instructional interactions between teachers and students'). The instrument is composed of two subscales: attitudes towards self-development (nine items) and

attitudes towards external recognition (three items). In their research with junior high-school teachers, Jhang (2020) established reliability coefficients of 0.95 and 0.89 for the respective factors, suggesting high levels of internal consistency among the items. As our hypothesis concerns teachers' attitudes towards self-development in Lesson Study, this instrument was well-aligned to our aims. In the present study, we achieved reliability coefficients of 0.91 95% CI [0.89, 0.92] and 0.66 [0.57, 0.74] for attitudes towards self-development and attitudes towards external recognition through LS, respectively.

Mathematics teaching self-efficacy

Mathematics teaching self-efficacy was measured using the 'Mathematical Practises – Teaching Efficacy and Expectancy Beliefs Instrument' developed by Riggs et al. (2018). As outlined above, this instrument was designed to capture teachers' beliefs in their ability to teach mathematics, with an emphasis on conceptual understanding and engaging in mathematical practices. Such mathematical practices include habits of mind for doing and teaching mathematics, such as engaging in productive struggle, developing and critiquing mathematical arguments, and seeking and using patterns in mathematics (Riggs et al. 2018). Given the context of curricular change in mathematics in Ireland that currently promotes teaching for understanding (Johnson, Freemyer, and Fitzmaurice 2019; Prendergast and Treacy 2018), this instrument was deemed suitable in this research.

This scale is divided into two subscales. Twenty (Max score = 100, Min. = 20) items measure self-efficacy in using mathematical practices and teaching for conceptual understanding (e.g. 'I can help students learn to see relationships between quantities'). Twelve items (Max score = 60, Min = 12) measure a teacher's belief in outcome expectation of using mathematical methods for conceptual understanding (e.g. 'Regardless of the teacher's instruction, students won't use available tools to investigate problems on their own'). Sub-scales can be utilised individually or as a total sum score of mathematics teaching self-efficacy and, in this research, we used a total sum score. Reliability coefficients of 0.91 and 0.84 for the respective subscales are reported by Riggs et al. (2018). Our scale data recorded reliabilities of 0.92 95% CI [0.91, 0.93] for self-efficacy in mathematical practices and teaching for conceptual understanding and 0.86 [0.85, 0.88] for outcome expectations, representing strong reliabilities.

Participation in lesson study

The online survey asked participants to report on how many cycles of Lesson Study they had completed to date. For simplicity, we presented participants with a multiple-choice item that asked whether they had participated in 0, 1 or 2 + cycles of Lesson Study. This was the primary dependent variable for the study.

Data analysis

Our analytical strategy takes cognisance of the exploratory-confirmatory data analysis (EDA/CDA) continuum (Tukey 1977), which is often missed by researchers who mistakenly adhere to strict CDA framing (Fife and Rodgers 2022). For this specific study, as is the case for most psychological and educational research, we are operating in rough CDA mode, where we have theorised working hypotheses to be modelled but which can be

refined if explicit reference to these decisions is reported (Fife and Rodgers 2022, 458). Rough CDA requires estimation approaches rather that null hypothesis significance testing (NHST) and, for this reason, we implemented an approach based on the comparison of models rather than on null hypotheses, which are far less informative of socially situated phenomena.

Core to the analytic approach for the present study is a reliance on the graphical representation of data and hypotheses, as well as visual inspection and inference to assess diagnostic criteria. The recent promotion of this approach in contemporary psychological and social science research arises from the multiple issues regarding questionable research practices in these fields. Moreover, relying on the human visual system is a more robust alternative to utilising statistical analyses of data diagnostics, given sensitivity and accuracy issues with standard available options under the traditional NHST paradigm (Fife 2021).

To examine our proposed hypothetical model (Figure 1), a generalised linear modelling (GLiM) approach was adopted. This was the most suitable analytical design for the study, given that our outcome or dependent variable was participation rates in Lesson Study, measured ordinally, which violates core assumptions of the ordinary linear model (the basis for most standard statistics). Principally, GliMs allow for the modelling of non-normal data through a nonlinear function, which enables the inclusion of non-continuous dependent variables, such as binary or categorical responses (Fox and Weisberg 2019).

All data screening and analysis was conducted in 'R' and all supplementary materials, as well as data, associated with this study, can be accessed at https://osf.io/cyxs6/.

Once data was tabulated, an exploration was undertaken. First, we screened for any missing data (partial or complete) in the online questionnaires; all cases were complete. Prior to building GliMs for the purpose of investigating our working hypotheses, all data was subjected to standard diagnostic inspections. Univariate outliers were screened using graphical inspections of the univariate distributions in conjunction, with an analysis of influential outliers using the median absolute deviation (MAD) method of Leys et al. (2013). The MAD overcomes the limitations of using the mean and standard deviation as the basis for evaluating influential outliers, which can be limited by the sample size of the study. MAD was detected using the 'Routliers' package in R (Delacre and Klein 2019). From the inspection of univariate histograms (see supplementary material in the link above), the data for teachers' attitudes towards self-development in Lesson Study demonstrated a significant negative skew. The results of the MAD detection indicated one outlier and, given the relatively small sample in this work, it was decided to treat this univariate outlier in order to preserve statistical power. Using the guideline of the Mean-3*MAD < Xi < Mean + 3*MAD (Leys et al. 2013), the outlier was transformed to equal the lower bounds of the MAD. This transformation is not strictly necessary when using a GliM but, to support any exploratory analyses using a continuous outcome, this transformation was conducted to mitigate the potential influence of this extreme value.

Findings

Descriptive statistics, including the essential demographics of the participants, are presented in Table 2. All GliMs in the present study were modelled using the 'ordinal' package (Christensen 2019).

Table 2. Descriptive statistics for study variables.

Sex	Variables	*n*	mean	95% CI [LL,UL]	SD	Min	Max	Skew	Kurtosis	SE
Male	Age	18	37.78	[32.31,43.25]	10.07	22.00	59.00	0.12	−0.94	2.37
Male	Years teaching	18	14.11	[9.06,19.16]	9.30	2.00	37.00	0.64	−0.23	2.19
Male	ALS	18	36.40	[32.73,40.07]	6.73	19.21	44.00	−1.13	0.49	1.59
Male	MTSE	18	85.60	[80.94,90.26]	8.58	71.00	98.79	−0.01	−1.46	2.02
Female	Age	46	35.96	[32.48,39.44]	10.25	23.00	65.00	0.89	0.39	1.51
Female	Years teaching	46	12.91	[9.59,16.23]	9.74	1.00	42.00	0.86	0.56	1.44
Female	ALS	46	37.20	[35.61,38.79]	4.65	27.00	45.00	−0.12	−0.85	0.69
Female	MTSE	46	82.06	[79.48,84.64]	7.60	68.00	98.79	0.47	−0.13	1.12

Note. Note: CI = confidence interval; LL = lower limits of 95% CI; UL = upper limits of 95% CI; SD = standard deviation; SE = standard error; ALS = attitudes towards self-development in Lesson study; MTSE = Mathematics teaching self-efficacy.

Participation as predicted by attitudes towards self-development in Lesson Study

To examine this first hypothesis using a model comparisons approach, it was first necessary to define a base model where the dependent variable is modelled with minimal predictors. In this case, we included a predictor of years of teaching experience, given the significance of this factor in affecting career motivation (Štemberger 2020). For example, Klassen and Chiu (2010) demonstrated that teachers' years of experience have a direct relationship to various self-efficacy typologies, including teaching self-efficacy. For the purposes of clarity throughout the modelling process, years of teaching were converted to a categorical variable based on quartiles of the sample which asked teachers to state the years of teaching experience they had at the time of the survey. The base model was:

Model 1 = *Lesson study cycles* ~ *Career stage.*

In a model comparison approach, this base model is used to determine the significance of adding predictor variables in stages by comparing to the primary model of interest. In the base model, Lesson Study cycles were entered as the dependent variable on the left and years of experience was entered as a categorical predictor on the right. The full results of this null model, as well as the cross-tabulation exploration, can be found in the OSF repository linked above. For our sample, there was no significant effect of years of teaching experience on Lesson Study participation.

Our first hypothesis concerned the role of attitudes towards self-development in Lesson Study in predicting participation rates. The visual associated with this model is presented in Figure 2 and depicts a small trend of increased attitudes as one completes further cycles.

In order to fully test this relationship, the following model was developed:

Model 2 = *Lesson study cycles* ~ *Career stage* + *Attitude towards self-development through lesson study.*

Model comparisons for hypothesis 1

The model comparisons approach in this study explicitly compares model 1 to model 2 to assess the best fit to the data. Several statistical tests are available to the researcher for the comparison of models and these must be selected based on the nature of the model applied to the data. For the present study, the likelihood-ratio test (LRT) was deemed

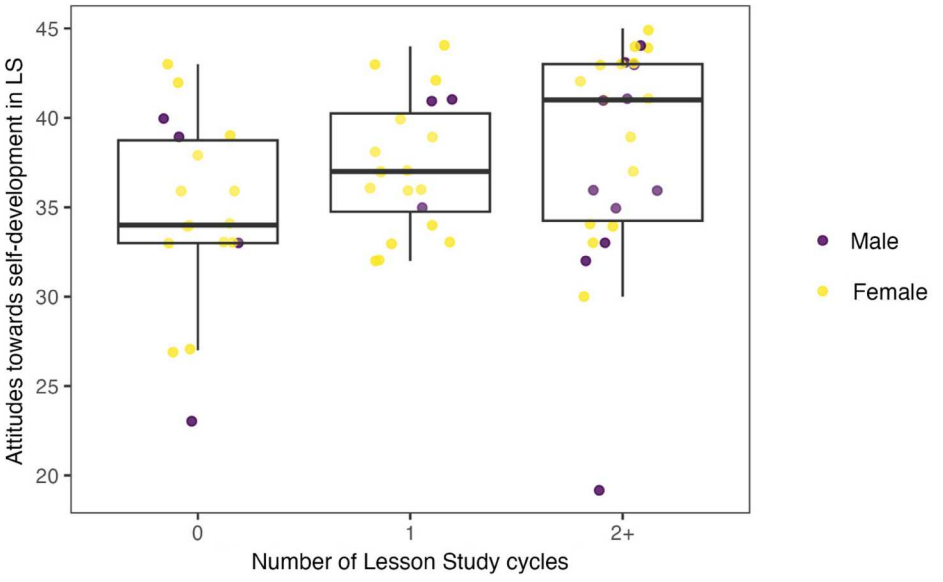

Figure 2. Attitudes towards self-development in Lesson Study plotted across cycles of participation.

suitable, as normal tests of comparisons, such as the Wald statistic, are incapable of accurately assessing GliM fit (Tabachnick and Fidell 2014, 505), especially in the case of ordinal outcomes. We also adopted the Akaike information criterion (AIC), which has been promoted by Fox and Weisberg (2019, 319) as informative for proportional odds/ordinal models. In addition, we also included a Bayes factor (BF) criterion to assess the probability of model superiority in the comparison.

In comparing the two models, model 2 represented an overall better fit to the data once career stage had been controlled for (AIC = 140.68, BF = 1.69, LRT (p = .02)), compared to model 1 (AIC = 143.89). For this reason, model 2 was selected as the optimal fit to our data and demonstrated the statistically significant effect of attitudes towards self-development in Lesson Study in predicting increased participation rates in Lesson Study, B_{model2} = 0.11; p = .028; 95% CI [.02, 0.22]. To support further inference from the model, estimated marginal effects were calculated using the 'ggeffects' package (Lüdecke 2018) and these are plotted for clarity in Figure 3.

Figure 3 demonstrates the predicted probabilities associated with model 2. Attitudes towards self-development in Lesson Study have a clear predictive relationship – over and beyond years of teaching experience – to participation rates in Lesson Study, with a teacher's probability of engaging with the approach significantly higher as their attitudinal rating increases. In the case of the '0 cycles' grouping, higher ratings on attitudes towards self-development in Lesson Study predict a lower probability – less than a 25% chance for scores from 40 to 45 on the scale – that a teacher will find themselves in this group. This demonstrates the salience of higher attitudes towards self-development in Lesson Study as a precursor to engagement during participants' professional working careers.

Interestingly, the role of attitudes seems exponentially pronounced in the 2 + cycles grouping, suggesting that positive attitudes towards self-development are important to

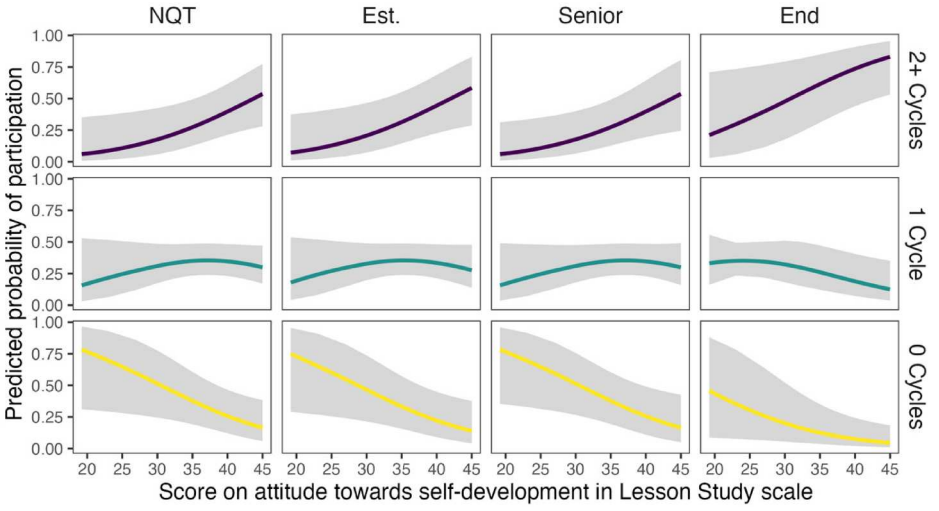

Figure 3. Predicted probabilities for attitudes towards self-development on participation in Lesson Study. Note. Career stages in current study are based on quartiles of years teaching experience recorded for study sample; NQT = Newly qualified teacher (<5 years); Est. = established teacher (5-11.5 years); Senior = Senior teacher (11.5-19 years); End = End quarter of career (>19 years).

sustained engagement with Lesson Study. There appears to be a form of plateau effect for the teachers that have completed a cycle of Lesson Study, with a decrease apparent in probability of participation in those with an attitude scoring in the 35–40 range. This seems to be more pronounced for participants in the 'end' category of career stage.

The mediating effect of self-efficacy

For the second hypothesis, we aimed to examine the potential mediating effect of mathematics teaching self-efficacy in the relationship between attitudes towards self-development in Lesson Study and participation in Lesson Study. In defining the full model for mediation, we are hypothesising mathematics teaching self-efficacy as the mediator (see Figure 1). Moreover, the core principle for conducting a mediation analysis is to test whether the effect of the independent variable (attitudes towards self-development in Lesson Study) on the dependent variable (Lesson Study participation) is reduced when the mediator is controlled (Judd, Kenny, and McClelland 2001). More specifically, a variable is considered to serve as a plausible mediator when (a) there exists a relationship between the independent variable and the mediator, (b) changes in the mediator account for changes in the dependent variable and (c) when direct and indirect paths from the independent to the dependent variable are controlled, the direct effect of the independent on the dependent variable is no longer significant (Baron and Kenny 1986). These are generally accepted assumptions in mediation analysis with linear models, but there are complications with the transfer of these assumptions to GliMs (Imai, Keele, and Tingley 2010) that contain ordered categorical outcomes, as in our study. As GliMs naturally violate linearity assumptions when the outcome or dependent

variable is discrete, parametric procedures are inapplicable. Imai, Keele, and Tingley (2010, 317) provide an algorithm for nonparametric mediation analysis as follows:

(1) Using a bootstrapping procedure (a) fit models for the independent variable and mediator variables, (b) simulate possible values of the mediator, (c) simulate possible outcomes given the simulated values of the mediator, (d) compute the causal mediation effects.
(2) Calculate summary statistics such as point estimates and confidence intervals.

Imai, Keele, and Tingley (2010) recommend a procedure based on bootstrapping using 1000 simulations as standard. For the purposes of our work, we adopted this procedure using the 'mediation' package in R (Tingley et al. 2014).

Firstly, the relationship between the independent variable and mediator was examined using the following model:

Mediation model = mathematics teaching self-efficacy ~ attitudes towards self-development in lesson study.

It should be noted that the full mediation analysis drops the variable of years of teaching experience, due to the insignificance of this as a predictor in hypothesis 1 for the current sample. This also allows us to preserve statistical power given the restriction to two predictors in our earlier reported power analysis. Attitudes towards self-development in Lesson Study had a significant effect on mathematics teaching self-efficacy (B = 0.38, 95% CI [.005, 0.75], $t(62) = 2.03$, $p = 0.047$), establishing the relationship between the mediator and the independent variable. In the next step of the analysis the full model of interest, with both the independent variable and the mediator included, was defined as follows:

Full model = Lesson study cycles ~ mathematics teaching self-efficacy + attitudes towards self-development in lesson study

Next, the mediation model and the full model were submitted to a non-parametric mediation analysis, with 1000 simulations, in line with the procedure of Imai, Keele, and Tingley (2010). The results of this analysis are presented in Table 3.

Based on the outcome of the mediation analysis, mathematics teaching self-efficacy completely mediates the effect of attitudes towards self-development on participation in Lesson Study. The total effect, without the mediator included in the model, is the only type that records significant *p* values and, once the mediator is included in the ACME, the effect of attitude is entirely filtered out. This complete mediation is also supported in the full results of the model fit analyses shown in Table 4.

Table 3. Results of bootstrapped non-parametric mediation analysis.

	0 cycles			1 cycle			2 + cycles		
Effect	Value	95% CI [LL, UL]	*p*	Value	95% CI [LL, UL]	*p*	Value	95% CI [LL, UL]	*p*
ACME	−0.002	[−.009, .001]	0.11	0.001	[−.001, .005]	0.13	0.0003	[−.0006, .004]	0.11
ADE	−.003	[−0.01, 0.002]	0.10	0.003	[−.0001, 0.007]	0.06	0.001	[−0.002, 0.005]	0.10
Total effect	−0.005	[−0.01, 0.002]	**0.04**	0.004	[.00001, 0.008]	**0.02**	0.001	[0, 0.006]	**0.04**

Note. ACME = Bootstrapped average causal mediation effect; ADE = Bootstrapped average direct effect (with mediator held constant); Total effect = Bootstrapped direct effect of the independent variable on the outcome without mediator included; 95% CI [LL, UL] = Bootstrapped 95% confidence intervals for mediation effects [LL = lower limits, UL = upper limits]; *p* = Bootstrapped *p*-values associated with the type of effect; Sample size used = 64; Simulations = 1000.

Table 4. Comparison of fit parameters for mediation models.

	Model [95% CI]	Mediated model [95% CI]
ALS	0.12*	0.09
	[0.02; 0.22]	[−0.01; 0.18]
MTSE	-	0.11**
		[0.04; 0.18]
AIC	139.35	131.15
BF	-	20.48
LRT	-	10.20***
Num. obs.	64	64

Note. ALS = Attitudes towards self-development in Lesson Study. MTSE = Mathematics teaching self-efficacy. AIC = Akaike information criterion. BF = Bayes factor. LRT = Likelihood ration test. Num. obs. = Number of observations.
*$p < .05$. **$p < .01$. ***$p < .001$.

Overall, the findings have demonstrated that attitudes towards self-development in Lesson Study are a significant predictor of participation in Lesson Study, with teachers who have completed two or more cycles illustrating higher scores in this variable. Additionally, we have shown that mathematics teaching self-efficacy mediates this relationship.

Discussion

This research has implications for those considering the introduction of Lesson Study in teacher education. The study set out to examine the relationship between teachers' attitudes towards self-development in Lesson Study and their participation rates in this form of professional development. In addition, we sought to investigate the role of mathematics teaching self-efficacy on teachers' participation in Lesson Study. Using survey data with pre-validated scales from a sample of practicing post-primary mathematics teachers, a rough CDA approach was adopted where we explicitly tested the models set out in our hypotheses and filtered different theoretically motivated factors to explore other potential relationships that may have emerged in the data. For our first hypothesis, which stated that teachers' attitudes towards self-development in Lesson Study would predict their participation rates, we found a statistically significant result confirming this hypothesis. This finding aligns with that of Jhang (2020) and highlights the salient role of motivational variables in predicting the likelihood of teachers participating in Lesson Study. This finding also outlines the necessity for clear communication around the model and practices within Lesson Study when attempting to introduce this model of professional development in an educational setting where it is culturally unfamiliar (Fujii 2014; Stigler and Hiebert 2016).

The findings from this research build on Jhang's (2020) work by also examining the variable of mathematics teaching self-efficacy in determining teachers' rates of participation in Lesson Study. The mediation analysis presented in Table 3 confirms our second hypothesis and demonstrates that mathematics teaching self-efficacy mediates the relationship between attitudes towards self-development in Lesson Study and participation rates, supporting this variable as a more salient motivational factor in sustained participation in Lesson Study. Our inclusion of teachers who have not yet engaged in Lesson Study provides initial evidence for the importance of appropriate levels of teaching self-efficacy as an underpinning motivational factor in encouraging first engagement

with this form of teacher education. This was demonstrated by the mediation of mathematics teaching self-efficacy over attitudes towards self-development in Lesson Study in predicting engagement, suggesting that positive self-belief as a mathematics teacher is critical to collaborative forms of professional development engagement. This finding resonates with research by Twohill et al. (2023) who outline the need for initial teacher education programmes to specifically focus on developing student teachers' self-efficacy to teach mathematics. We further echo this finding since this research suggests that newly qualified teachers with a stronger sense of teaching self-efficacy are more likely to participate in Lesson Study. Furthermore, our research suggests that positive experiences of Lesson Study contribute to a positive attitude towards self-development in it. In this regard, ITE providers may wish to incorporate Lesson Study in their programmes to further encourage their student teachers in their continuum of learning in collaborative settings as newly-qualified teachers in school contexts.

The importance of mathematics teaching self-efficacy with regards to participation is a notable finding for the Irish context, given the nature of curricular reform in mathematics in recent years. Our research suggests that a teacher's belief in their ability to teach for conceptual understanding and incorporate mathematical practices explains some of the variance in their initial decision to pursue Lesson Study in the first instance. Furthermore, an individual's mathematics teaching self-efficacy is related to their sustained and continued participation in further Lesson Study cycles. This finding is important considering that in Jhang's (2020) research, some teachers failed to complete even one full cycle of Lesson Study, in addition to recent research findings from Ledinez Munoz et al. (2023) demonstrating student teachers' increased self-efficacy due to their participation in theory-based Lesson Study.

A directional conclusion cannot be reached from this data alone. However, given that other research has found that Lesson Study can enhance student teachers' self-efficacy (Ledinez Munoz et al. 2023), this may explain some of the increased rates of teaching self-efficacy in individuals with higher participation rates. To build further on the work of Ledinez Munoz et al. (2023), it would be useful to conduct research to explore this potential phenomenon with in-service teachers.

A plateau effect was found for teachers who participated in only 1 cycle of Lesson Study (Figure 3) and is difficult to interpret this finding in this context. It could indicate a sub-sample of teachers who have experienced Lesson Study but are no longer interested in subsequent cycles. This may highlight a threshold of development, which must be exceeded in an initial cycle of Lesson Study if teachers are to see value in further participation. It is possible that factors such as school-based limitations (e.g. timetable, workloads) are mitigating against some teachers exceeding a threshold necessary to observe further participation as valuable to them (e.g. Lewanowski-Breen, Ni Shuilleabhain, and Meehan 2021). This finding may also indicate that these teachers have not fully engaged in Lesson Study or had unsatisfactory participation in it due to a lack of adherence to the model. Research by Ni Shuilleabhain et al. (in press) suggests that elements of Lesson Study have been misunderstood or misconstrued in the national-scale implementation at post-primary level in Ireland. Such findings, including those of this research, may indicate that the communication and introduction of Lesson Study, as a culturally unfamiliar practice (Stigler and Hiebert 2016), should be carefully considered by those hoping to introduce it to new educational settings.

Conclusion

While current education policies encourage teachers to work collaboratively (Moynihan and O'Donovan 2022), the challenge is finding models which allow teachers to exercise their autonomy and professional judgements and then sustaining these practices over time. Investigating teachers' motivations to participate in Lesson Study is relevant to the successful implementation of such collaborative policies and may provide insight into building capacity and teacher community in schools (e.g. Lewanowski-Breen, Ni Shuilleabhain, and Meehan 2021).

Lesson Study has the potential to act as a way for teachers to engage in situated, relevant, timely research into their own practices and environment, thereby improving teaching and learning experiences for all members of the school community (Curran 2020; Hourigan and Leavy 2022; Ni Shuilleabhain and Seery 2018). Lesson Study may also play an important role in school self-evaluations where teachers can generate evidence on teaching and learning, curriculum, students' experiences, etc., through the careful construction and reflection of lessons. In the context of the provision of 'professional time' for professional collaborative activities (DES, 2019), providing teachers with structured opportunities to participate in phases of a Lesson Study cycle may be a useful way to support teachers in introducing present and future curriculum reform. In attempting to incorporate Lesson Study as a model of professional learning, our research demonstrates that due regard must be given to potential participants' teaching self-efficacy and attitudes towards self-development in this model of professional development.

Disclosure statement

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