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From beginning to mature: investigating the development of teacher community through Lesson Study

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This research investigates the potential of Lesson Study to develop teachers' professional community. Situated in two case study schools, Doone and Crannog (both pseudonyms), where mathematics teachers participated in multiple, successive cycles of Lesson Study over the course of one academic year, the research details the development of teacher community through teachers' conversations and reflections. Data was generated through audio recordings of teachers' Lesson Study meetings and individual interviews with participating teachers. Analysis is based on a framework of professional teacher community which describes discrete phases of development from beginning to mature. Findings from the research suggest that groups of teachers may begin their Lesson Study work at different stages of evolution of teacher community and that Lesson Study has the potential to strength and develop such community over successive cycles. The research demonstrates that teachers' participation in Lesson Study can provide them with opportunities to recognize and express communal responsibility for individual growth of colleagues, a key feature in the formation of teacher community. The research also highlights the importance of navigating fault lines or differences in ideas and opinions during the Lesson Study work. Findings may offer guidance to facilitators of Lesson Study on elements of teachers' collaborative work which may benefit from additional focus, such as productively engaging with conflict within a group. This research contributes to the literature on Lesson Study in outlining how this model of professional development may provide a powerful structure within which teacher community can be developed.

KEYWORDS

Lesson Study, teacher community, mathematics teachers, professional learning community, professional development

1 Introduction

Teachers' professional collaboration has been established as a key factor in educational improvement and innovation (Giles and Hargreaves, 2006). Collaboration through professional learning communities has been found to increase teacher retention, boost student achievement, and enhance the implementation of innovation and change (Hargreaves, 2003; McLaughlin and Talbert, 2006; Stoll et al., 2006; Darling-Hammond et al., 2009; Lomos et al., 2011). In addition, teachers' collaboration in learning communities has been found to build teacher identity (Lieberman, 2009) and contribute to generating collective creativity, shared values, and a common vision for teaching and learning (Hord, 1997). Teacher communities

can also provide teachers with a structure within which to engage with curricula and policies (Dooner et al., 2008), important actions within the context of educational reform. There remains a question, however, as to how schools and educational systems can deliberately design and support the cultivation of teacher collaboration in learning communities for sustainable professional development. This is particularly relevant in educational contexts where teaching is often considered as work which is done in isolation in a teacher's classroom (e.g., Moynihan and O'Donovan, 2022; Capone et al., 2023).

In this research we refer to teachers' professional collaboration as teacher community and define this as the collaborative work undertaken by a group of teachers, which is rooted in the premise of improving both teacher practice and student learning (Grossman et al., 2001). Lesson Study has been highlighted as a model of professional development within which teachers can collaborate to develop and share practice, while focused on improving students' learning experiences (Lewis C., 2016; Lewis and Perry, 2017). In this paper we focus on Lesson Study as a mode of teachers' professional collaboration and investigate the development of teacher community within this form of teacher education.

Research has demonstrated that participating in Lesson Study can support teachers in establishing a learning community by developing their professional language and collaborative competence (Lewis et al., 2009; Lieberman, 2009; Gunnarsdóttir and Pálsdóttir, 2019). Through collaborative professional experimentation in Lesson Study, teachers have been found to adapt and change their pedagogical practices (Takahashi, 2014; Schipper et al., 2017; Ní Shúilleabháin, 2018) and studies have demonstrated positive impacts on student achievement due to teachers' participation in Lesson Study (Lewis and Perry, 2017; Wake and Joubert, 2023). In the context of this Special Issue focusing on Lesson Study in STEM (science, technology, engineering, and mathematics), research by Baricaua Gutierez (2016) demonstrated that science teachers' participation in Lesson Study contributed to building a collaborative and professional working environment. Within the mathematics domain, Cajkler et al. (2014) found that collaborating in Lesson Study created a stronger sense of teacher community and helped teachers to develop more student-centered approaches. Lesson Study, therefore, has been found to be a useful form of advancing teacher learning, through the development of community, across STEM subjects.

While research outlined above has demonstrated the potential of Lesson Study to generate teacher community, little is known about how core features of teacher community develop through teachers' participation. In this paper we investigate how teacher community, as defined by Grossman et al. (2001), develops through Lesson Study and attempt to address the research question:

> *How do core features of teacher community emerge and develop through teachers' participation in successive cycles of Lesson Study?*

Our study focuses on two post-primary school sites, where Lesson Study was introduced to mathematics teachers who participated in a number of cycles of Lesson Study over one academic year. Previous research has identified how these teachers' participation in Lesson Study contributed to the development of their pedagogical content knowledge (PCK) (Ni Shuilleabhain, 2016) and how participating in Lesson Study encouraged them to enact curriculum reform within their classrooms (Ní Shúilleabháin, 2018). Research involving a number of these participants several years later found that teachers in both schools reflected positively on their Lesson Study experiences and reported on a more developed sense of community in their schools since their participation (Lewanowski-Breen et al., 2021). However, research was not undertaken to ascertain how teacher community may have developed during the teachers' participation in iterative cycles of Lesson Study. In this paper, we revisit the data generated in teachers' Lesson Study work with a view to unpacking how such communities may have matured through their collaborative endeavors.

2 Lesson study and teacher community

2.1 Developing teacher community

Rousseau (2004) defines the principles of teacher community as: sustained inquiry of members around their own practices; shared inquiry within the group without trepidation of the implications on one's own knowledge or beliefs; and a clear goal to work toward. Such aspects of teacher community are especially important in the context of STEM, and particularly mathematics, where content and PCK play a core role in the classroom practice of teachers (Krauss et al., 2008; Park et al., 2011) and can affect the efficacy of teachers in their own practice (Riggs et al., 2018). While much research has extolled the values of teacher community in education, the literature also highlights the precariousness of teacher community which can sometimes be fragile and transient (Smith Senger, 1998; Rousseau, 2004). Groups can struggle to develop into sustainable communities and therefore fail to positively impact student learning. In this regard, it is important to highlight the core features of the development or maturation of community and attempt to prepare teachers for them when introducing new collaborative practices.

Teacher communities can undergo change over time and, arguably, need to do so to allow for a convergence in collaborating teachers' perspectives on the work and shared goals of the group (Dooner et al., 2008). To ensure a community is sustainable in a school context it needs to be able to adapt to members leaving and joining (van Es, 2012). Dissent and conflict also need to be a workable part of the community (Grossman et al., 2001; McLaughlin and Talbert, 2006; Dooner et al., 2008). Grossman et al. (2001) outline a framework for teacher community formation which defines the features of community over phases of 'beginning,' 'evolving,' and 'mature.' These are outlined over four categorizations incorporating some of the features outlined above, thereby providing a matrix of stages of teacher community formation (see Table 1).

2.2 Teacher community and teacher talk

By breaking down the barriers of the isolated classroom, collegiate and collaborative relationships can lead to an increased sense of satisfaction and effectiveness on behalf of individual teachers (Little, 1993). Through exchanging knowledge, sharing teaching experiences, and collectively working to generate solutions to specific teaching and learning issues, teachers in professional communities are provided with opportunities to build confidence in their collective capability to

TABLE 1 Framework for the formation of teacher community as outlined by Grossman et al. (2001).

Beginning	Evolving	Mature
1. Formation of group identity and norms of interaction		
Identification with subgroups	Pseudocommunity (false sense of unity: suppression of conflict)	Identification with whole group
Individuals are interchangeable and expendable	Recognition of unique contributions of individual members	Recognition that the group is enriched by multiple perspectives (sense of loss when member leaves)
Undercurrent of incivility	Open discussion of interactional norms	Developing new interactional norms
Sense of individualism overrides responsibility to group	Recognition of need to regulate group behavior	Communal responsibility for and regulation of group behavior
2. Navigating fault lines		
Denial of difference	Appropriation of divergent views by dominant position	Understanding and productive use of difference
Conflict goes backstage, hidden from view	Conflict erupts onto mainstage and is feared	Conflict is expected feature of group life dealt with openly and honestly
3. Negotiating the essential tension		
Lack of agreement over purposes of professional community; different positions viewed as irreconcilable	Begrudging willingness to let different people pursue different activities	Recognition that teacher learning and student learning are fundamentally intertwined
4. Communal responsibility for individual growth		
Belief that teachers' responsibility is to students not colleagues; intellectual growth is the responsibility of the individual	Recognition that colleagues can be resources for one's learning	Commitment to colleague's growth
Contributions to the group are acts of individual volition	Recognition that participation is expected from all members	Acceptance of rights and obligations of community membership (e.g., "intellectual midwifery," "press for clarification")

motivate students and incorporate pedagogical reform (Darling-Hammond et al., 2009; Moolenaar et al., 2012). Teachers working in collaboration with colleagues tend to have a wider skill variety, be more informed about their students' performance, and be more aware of their colleagues' work (Louis and Marks, 1998; McLaughlin and Talbert, 2006; Moolenaar et al., 2012).

Teacher talk is a core element of teacher community, where learning is based on the premise of collaborative interactions. Articulating and sharing ideas or practices provides opportunities for teachers to explore different perspectives beyond their own already acquired beliefs and experiences (Grossman et al., 2001; Slavit et al., 2013). Much research has been undertaken on the types of talk visible in teachers' learning interactions with one another. However, research has found that teachers' conversations can sometimes be superficial and congenial in nature in order to avoid feelings of fear and insecurity (Grossman et al., 2001; Nelson et al., 2010). Littleton and Mercer (2013) have categorized such forms of talk as 'cumulative,' where teachers simply agree with the thinking of one person to avoid conflict. They contrast this 'cumulative' talk with 'disputational' talk, where teachers are not looking for any alignment of their thinking and where engagements can be considered as hostile. They highlight 'exploratory' talk, where teachers engage in critical and constructive interactions with one another, as key to the sharing and building of knowledge within teacher collaboration (Littleton and Mercer, 2013). Such 'exploratory' talk has been found to be important in leading to teacher learning in Lesson Study (Dudley, 2013; Warwick et al., 2016; Clivaz et al., 2023; Vermunt et al., 2023).

2.3 Lesson study and teacher community

The principles of teacher community defined by Rousseau (2004), outlined above, align well with the work of Lesson Study where: the shared goal of engaging in a Lesson Study cycle is important to working successfully together (Chichibu and Kihara, 2013), teachers establish a collective vision for their Lesson Study group (Lewis et al., 2009; Lewis and Perry, 2017) and teachers are encouraged to critically reflect on their practice, making their implicit knowledge, beliefs, and practices explicit (Takahashi and McDougal, 2016; Fujii, 2018). Doig et al. (2011) highlight the importance of teachers sharing their professional perspectives in communities of inquiry through Lesson Study.

As expanded on below, and elsewhere in this Special Issue, the phases of Lesson Study across a cycle are outlined as successive steps but often happen in a more blended nature, with planning meetings sometimes incorporating revisions of the research theme and reflection meetings often including revisions or further planning of lessons (see Clivaz and Ni Shuilleabhain, 2019). This is outlined in detail by Dotger and Burgess (2022), who describe the phases of Lesson Study with relevance to their origins in Japan. For the purposes of this study, aligning with the model introduced to teachers participating in previous research (Lewis et al., 2009), we consider the phases of Lesson Study as outlined (Table 2).

Lesson Study can be considered as an intervention model that supports professional development by explicitly creating a context for collaborative, professional interaction (Warwick et al., 2016). Participating in Lesson Study helps teachers to establish a shared sense

TABLE 2 Phases of a lesson study cycle adopted from Lewis et al. (2009).

Lesson study cycle	
1	Articulation of the Shared Vision and Research Theme for this Cycle of Lesson Study (and potentially beyond)
2	Planning the Research Lesson (within a wider unit of learning)
3	Conducting the Research Lesson (and generating data from students' and teachers' work during the lesson)
4	Reflection of the Research Lesson (while recording potential changes to be made to the Research Lesson)

of responsibility for students' learning through collective decision-making (Lawrence and Chong, 2010) and taking part in Lesson Study encourages teachers to critically reflect on their pedagogical practices (Takahashi and McDougal, 2016). The dialogic space provided to teachers within the phases of Lesson Study gives rise to knowledge-sharing and knowledge-building exchanges (Ni Shuilleabhain, 2016; Warwick et al., 2016) and helps to establish shared knowledge of the group (Lewis and Perry, 2017).

Lesson Study has been found to influence teachers' classroom practices (Saito et al., 2006) and has been introduced in a number of educational systems as a mechanism to support educational reform (Lee and Ling, 2013; Takahashi, 2014). Some of these positive outcomes have been attributed to the fact that the teachers work as a professional community, supporting both student and teacher learning through their joint endeavors (Lieberman, 2009; Lewis C., 2016). As noted above, teachers have reflected on the development of their own sense of teacher community due to their participation in Lesson Study (Lewis et al., 2009; Cajkler et al., 2014; Lewanowski-Breen et al., 2021). Little is known, however, about how successful Lesson Study can be in developing teacher community and, if this is the case, what elements of Lesson Study can support such development (Ding et al., 2024).

Lesson Study has been demonstrated to enhance collaboration and cooperation across various STEM subjects, both for teachers and students: Lesson Study has been conducted within the subjects of physics (Capone et al., 2022), biology (Allen et al., 2004), chemistry (Conceição et al., 2019) and, as a large focus of Lesson Study work, in mathematics (e.g., Lewis and Perry, 2017; Clivaz et al., 2023; Vermunt et al., 2023). It is necessary, however, that teachers maintain fidelity with the Lesson Study model for impacts to teacher and student learning to be achieved (Bjuland and Mosvold, 2015; Lewis and Perry, 2017; Seleznyov, 2019). Fernández (2010) also outlines the importance of teachers feeling comfortable with contributing ideas, raising alternative perspectives, and supporting views with evidence from within their Lesson Study work. In cases where such Lesson Study conversations have occurred, evidence of teacher learning has been demonstrated (Lewis and Perry, 2017; Vermunt et al., 2023). The role of a facilitator may be important in this regard and particularly where Lesson Study is unfamiliar to the participants (Lewis J. M., 2016).

2.4 Lesson study and STEM education in Ireland

As highlighted within this Special Issue, STEM education has come to the fore in many jurisdictions and national policies since it was first brought into use as a term by the National Science Foundation in the United States in the 1990s (Delahunty and Ni Riordain, 2022). Ireland published its first STEM Education policy in 2017 and, like the US focus, has cited the need for quality provision within the field to establish Ireland as a 'technological creativity and innovation leader' (Department of Education, 2017). Such national policies have a direct impact on curricula across all levels of education and relatedly on teachers and students themselves (Delahunty and Ni Riordain, 2022). Ireland's STEM Education policy specifically highlights the subject of Mathematics as underpinning all STEM learning activities (Department of Education, 2017). Aligning this focus on STEM with a need to support high-quality teaching, Ireland's most recent STEM Education policy specifically highlights "cultures of collaborative professionalism" within schools (Department of Education, 2017, p. 15) and states that teachers' STEM education practice should "be supported through individual and collective reflection" (*ibid*). In parallel, the most recent national school self-evaluation guidelines, which aim to provide a shared understanding of what effective pedagogical practices look like in the Irish school system, recognizes "career-long professional development as central to the teacher's work and firmly situates reflection and collaboration at its heart" (Department of Education, 2022, p. 9). In this regard, with its incorporation of collaborative practices and elements of explicit reflection, Lesson Study aligns well with the outcomes and practices envisioned by teacher education and STEM education policy in Ireland.

Continuing teacher education for practicing teachers in Ireland largely manifests as days of 'in-service' (Gilleece et al., 2009). As part of the reform of the post-primary mathematics curriculum which began in 2010, teachers were offered 10 days of out-of-school learning to familiarize themselves with the content and pedagogy changes espoused within the reform. These days of learning have been characterized by teachers as "a bit like going to McDonald's – in the moment you feel satisfied, you feel great, but an hour later you are hungry" (White et al., 2021, p. 396). While teachers have been recorded as being familiar and aware of the mathematics curriculum reform, many have felt they have not had the relevant or sufficient resources to enact it in their classrooms (Neururer and Ni Shuilleabhain, 2022), thereby reflecting an 'implementation dip' highlighted by Fuller and Johnson (2001). Despite the resourcing of much teacher education in mathematics in Ireland, there has been little evidence demonstrating any reform-oriented changes in classroom practice (Jeffes et al., 2013; Prendergast and O'Donoghue, 2014). There is therefore a need to consider other models of teacher education which can support teachers to consider, enact, and reflect on their classroom practices. The school-based context of such models of teacher learning should be investigated, particularly in the context of new policies (outlined above) emphasizing collaborative teacher learning and the need highlighted by school leaders to challenge an "isolationist" culture of teaching in Ireland (Moynihan and O'Donovan, 2022).

Where Lesson Study has been conducted in school-based teacher groups in Ireland, allowing teachers autonomy in their participation both at primary and post-primary level, it has led to discernible changes in classroom practice and teachers' considerations of pedagogy (Ní Shúilleabháin, 2018; Mulligan, 2021). If we are to consider Lesson Study as a model which should continue to be supported within schools we should investigate other outcomes it may have which may be of additional benefit to schools, such as the

TABLE 3 Lesson study cycles and meetings at Doone and Crannog.

Cycle	1	2	3	4
Doone	5 planning meetings 1 post-lesson discussion (~8 weeks)	4 planning meetings 1 post-lesson discussion (~4 weeks)	2 planning meetings 1 post-lesson discussion (~4 weeks)	4 planning meetings 1 post-lesson discussion (~6 weeks)
Crannog	5 planning meetings 1 post-lesson discussion (~8 weeks)	3 planning meetings 2 post-lesson discussions *Note: Research Lesson was revised and re-taught after first reflection meeting* (~7 weeks)	4 planning meetings 1 post-lesson discussion (~7 weeks)	N/A

potential to generate teacher community and, therefore, contribute to teacher learning, satisfaction, and retention (Stoll et al., 2006; Moolenaar et al., 2012).

3 Methodology

3.1 Research approach

This research is conducted on two sites and investigates how a group of teachers' participation in Lesson Study may impact on their status of teacher community. Acknowledging that each group of teachers in a school is profoundly embedded in their particular environment and exists as network of multiple relationships (Tagnin and Ni Riordain, 2022), we attempt to consider each group as a whole and within its real-life context (Yin, 2014). The research therefore lends itself to a case study approach since the phenomenon of interest, i.e. the development of teacher community, involves the study of a contemporary phenomenon within a bounded system and has a level of complexity that requires multiple data sources to gain an in-depth understanding (Creswell, 2007; Yin, 2014). We adopt a multiple case-study approach, generating data in two post-primary schools (detailed further below) and, in the first instance, consider if and how the participating groups of mathematics teachers can be considered as a teacher community.

3.2 Research context and data generation

An invitation to participate in the research was sent to post-primary schools in an urban area through their school leaders. Two schools, Doone and Crannog (all names used throughout the paper are pseudonyms), volunteered to take part after an information presentation with mathematics teachers. Doone school was a large (>500 students), single-gender (boys), non fee-paying school and Crannog was a large, mixed-gender, fee paying school.[1] Ethical approval for the research was granted through the Ethics Committee within the School of Education at Trinity College Dublin. School leaders in both sites approved teachers' participation in the research and an additional stipend was given to both schools (sponsored by the National Council for Curriculum and Assessment) to account for any additional supervision and substitution that might be required for teachers to participate in Lesson Study. This additional funding was sought to attempt to negate any barriers that might discourage school leaders from allowing teachers to participate in the research (Takahashi and McDougal, 2016; Heckathorn and Dotger, 2022).

Five mathematics teachers in Doone and seven mathematics teachers in Crannog participated in the year-long study, where Lesson Study was introduced as a new and unfamiliar form of professional development. Teachers in both schools wanted to participate in the research to support them in implementing the curriculum reform that had been introduced in the previous year (Ní Shúilleabháin, 2018). As outlined in detail in Ní Shúilleabháin (2018), participating teachers' years of experience ranged from one to 35 years and a number of teachers reported themselves as "out-of-field" (three of the teachers in Doone and two of the teachers in Crannog), meaning they were not specifically qualified to teach mathematics (Ní Ríordáin and Hannigan, 2011). Four cycles of Lesson Study were completed in Doone and three cycles were completed in Crannog (with one cycle incorporating a re-planning and re-teaching of the Research Lesson) across a variety of mathematical topics and year groups. Teachers had autonomy in deciding what topics they wished to focus on throughout their Lesson Study work, how long they would spend planning a Research Lesson, and with which year groups and classes of students Research Lessons would be conducted. It is important to note here that, unlike the teachers observed by Perry and Lewis (2009) who lacked facilitator guidance in the initial phases of a Lesson Study cycle, the teachers participating in this research were facilitated in their Lesson Study work throughout all cycles by the first author, who acted as a participant researcher. In this role, the first author guided teachers through their first engagement with Lesson Study utilizing 'Lesson Study Step by Step' (Lewis and Hurd, 2011) as a guidebook. Additionally in this role, the first author provided teachers with relevant mathematics education resources when requested or as necessary.

Building on the literature of Lesson Study, we focus on teachers' talk within Lesson Study meetings and their individual reflections of their participation (Dudley, 2013; Warwick et al., 2016; Clivaz and Ni Shuilleabhain, 2019). Qualitative data were generated through audio recordings of Lesson Study meetings in both schools (~36 h) (see Table 3) and individual teacher interviews (semi-structured) at the beginning, mid-point, and end of the academic year.

1 Fee paying schools in Ireland are schools where students pay additional fees to attend the school, but the majority of teachers within the school are paid salaries through the Department of Education. Approximately 6% of all post-primary schools are fee-paying and they are mostly found in urban areas. Gender is noted here as a point of educational context only. In Ireland single-gender schools constitute 30% of all post-primary schools.

TABLE 4 Stages of formation of teacher community across cycles of lesson study at Doone.

Doone	1	2	3	4
Number of coded conversation excerpts	*151*	*166*	*60*	*89*
Beginning	46.21%	9.09%	14.24%	2.62%
Evolving	26.07%	40.18%	30.34%	25.09%
Mature	27.72%	50.73%	55.42%	72.29%

TABLE 5 Stages of formation of teacher community across cycles of lesson study at Crannog.

Crannog	1	2	3
Number of coded conversation excerpts	*146*	*101*	*115*
Beginning	6.91%	3.3%	3.08%
Evolving	56.73%	62.15%	52.07%
Mature	36.36%	34.55%	44.85%

3.3 Data analysis

Audio recordings of all Lesson Study meetings and interviews were transcribed, with multiple listenings occurring before coding to ensure accuracy of the transcription. Analysis was conducted utilizing NVivo software by two of the authors. This decision was informed by the volume of data and NVivo was chosen over other packages because it allowed the researchers to import documents directly from a word processing software, to easily code these documents, and efficiently retrieve and organize coded text (Tagnin and Ni Riordain, 2022).

Two of the authors undertook analysis of the qualitative data recorded utilizing Grossman et al.'s (2001) model of the formation of teacher professional community. In this model, the core categories of 'formation of group identity and norms of interaction,' 'navigating fault lines,' 'negotiating the essential tension,' and 'communal responsibility for individual growth' are outlined as relevant to three stages of community development (Grossman et al., 2001) and codes were aligned with the sub-categories of these (Table 1). Aligning with similar research on teacher talk in Lesson Study (Cajkler et al., 2014; Clivaz and Ni Shuilleabhain, 2019; Clivaz et al., 2023), conversational data from Lesson Study meetings were segmented into episodes or stanzas of several turns of speech between two or more teachers which were (1) relevant to the work of Lesson Study and (2) related to one of the 27 sub-categories of formation of teacher professional community (Grossman et al., 2001; Lewanowski-Breen et al., 2021). Items were coded as belonging to one and only one code within the framework. Similar to analysis undertaken by Cajkler et al. (2014) and Clivaz and Ni Shuilleabhain (2019), the coded elements varied in length due to the nature of the dialogue and the focus of the codes. In line with this approach it should be noted that the total number of coded episodes per cycle was not always the same, with the percentage of total speech coded within a cycle varying from 13 to 30% across both sites (see Tables 4, 5). With respect to teachers' interviews, only responses relevant to the development of teacher community were coded as a way of triangulating findings from the teacher talk data. At the first stage of analysis the first author coded the teacher interviews and conversation transcripts from Doone, using the *a priori* codebook (see Table 1). Having discussed the codes and conversations, both the first and second author then coded a cycle of data from Crannog as a check for reliability. Discrepancies were discussed until consensus was reached. The second author then coded the remaining conversation transcripts from Crannog and the first author coded the remaining interviews using the codebook and based on the collaborative conversations had.

As the research is based on two case-study sites, the analysis was approached as analytic generalizations (Wong, 2014) to illustrate how the interactions between teachers in both communities account for the development of specific features in those communities. Temporal points of the evolving stages of development of teacher community were taken based on a full cycle of Lesson Study, which typically occurred over 4 to 8 weeks (see Table 3).

3.4 Validity of the research

Since the first author of this paper took part in the generation of the data as a participant researcher, analysis of the development of both teacher communities did not commence until some years after data generation had been completed. With this passing of time, the authors feel that an analysis of the data based on the internal workings of each of the communities was sufficiently removed from the personal interactions of the first author. In addition, a double coding of teachers' dialogue and triangulation of the data from teachers' individual interviews and strengthens the validity of the findings in this paper. The authors recognize that the research is based on two case studies and, while case study research can lack generalizability, case studies that are representative of particular phenomena can generate empirical generalizations (Tagnin and Ni Riordain, 2022). The findings of this research may point toward some of the structural features of Lesson Study and teacher talk which may lead to development or maturation of teacher community.

4 Findings

As outlined above, research has identified Lesson Study as a vehicle for developing teacher community (Lewis et al., 2009; Lewis C., 2016). This paper builds on the extant literature by analyzing case study data through mathematics teachers' participation in Lesson Study to investigate the formation and maturation of teacher community. Excerpts of qualitative data are utilized to provide the reader with insights into the development of teacher community in both case study schools.

It is important to note that not all participating teachers were present in all Lesson Study meetings throughout the academic year, with one or two teachers absent for a meeting during each cycle. This was to be expected in these school environments as, recognizing the cultural factors affecting participation in Lesson Study (Stigler and Hiebert, 2016), teachers were not formally recognized for their participation in this professional development and sometimes had other school commitments to attend to.

4.1 Initial stage of development of teacher communities

Both groups of teachers began their participation at quite different stages of formation of teacher community, as identified by Grossman et al.'s (2001) model of formation of teacher professional community (see Table 6). Doone, which had few norms of teacher collaboration within the mathematics department, had more prevalent 'beginning' stage of formation features of teacher community at the end of Cycle 1. The school context is very relevant here since, at the commencement of the research, these teachers did not commonly work together, subject departmental meetings were rare and, when they did occur, generally focused on collective issues such as setting end-of-term examinations for year groups. In this school the teacher lounge was the only shared space occupied by teachers and there was no working area for teachers to meet or collaborate. Teachers did not have a regular time to meet and, when they did, it occurred during their 'free' periods as a voluntary act. Teachers rarely, if ever, spoke about pedagogy with one another and only shared resources with their own self-identified sub-groups of colleagues – a sub-category of a 'beginning' phase of teacher community (Grossman et al., 2001).

A number of mathematics teachers within Doone had chosen not to participate in the research and participating teachers, overall, saw themselves as the less established or more peripheral teachers in the department. Throughout teachers' talk in this first cycle there were examples of a 'beginning' phase of teacher community with undercurrents of incivility, denial of difference and conflict going backstage (Grossman et al., 2001). An example of an undercurrent of incivility is in the following interaction where one teacher, Kate, initially resisted the idea of focusing on a particular topic (Pythagoras' theorem) for the Research Lesson, as she felt it was too easy topic to teach. Focusing on this topic in their collaborative planning would, in her opinion, only result in her having to give away her good ideas to these other teachers.

> Lisa: We were thinking, rather than jumping in in the middle of all of this, that we'd do Pythagoras.
> Kate: Really? I think Pythagoras is really easy to do.
> Lisa: Right. You see…ahhhh…we are going to be starting, we are going to be into algebra there all the way along.
> Kate: Could we just do, like, factorizing?
> Micheal: Yeah.
> Lisa: Yes, okay.
> Kate: Like, it's going, it's easy to do, but it's hard to kind-of – I don't know. No, it is easy to do as well. We can do Pythagoras, that's fine.
> Lisa: Well, the other one is coordinate geometry… You could do that rather than Pythagoras.
> Kate: I…We'll do Pythagoras. It's fine. I'll just give you all my good ideas!

The conversation excerpt outlines an example of incivility "clothed in a jocularity that provoked laughter but left a sting in its wake" (Grossman et al., 2001, p. 962). It demonstrates Kate's mistrust in her colleagues' ability to teach this topic well and suggests an element of power distribution (Corcoran, 2011) in considerations of those who lack qualifications to teach mathematics (i.e., out-of-field teachers). In contrast, conversations from the first cycle of Lesson Study at Crannog demonstrate that the teacher community was already at an 'evolving/mature' stage of community (see Table 6). In this school there was a designated classroom area in the school for Mathematics and teachers regularly interacted outside each other's classrooms. There was also a designated physical space for teachers to work separate to the teacher lounge (something which is unusual in most schools in Ireland) and participating teachers often found themselves discussing classroom practice or sharing resources when working in this area. While there were a small number of mathematics teachers who chose not to participate in the research, the majority of mathematics teachers had volunteered to take part and there was a sense of identity of the whole department as a defined group – a feature of a 'mature' teacher community (Grossman et al., 2001). Other elements of teachers' interactions demonstrated their 'evolving' stage of teacher community, where there was a recognition of the contributions of individual members of the group. One example is the excerpt below where Dave shared a new piece of content knowledge he had learned with his colleagues, who demonstrated interest in this unprompted contribution from one of their less-experienced peers.

> Dave: Do you know why they are called quadratics? I read it last night…
> Walter: What is it?

TABLE 6 Stage of formation of teacher community at end of cycle 1.

Cycle 1	Beginning	Evolving	Mature
Doone	*46.21%*	*26.07%*	*27.72%*
Formation of group identity and norms of interaction	34.15	10.51	14.49
Navigating fault lines	11.01	6.44	13.23
Negotiating the essential tension	0	0	0
Communal responsibility for individual growth	1.05	9.12	0
Crannog	*6.91%*	*56.73%*	*36.36%*
Formation of group identity and norms of interaction	3.88	17.95	1.35
Navigating fault lines	1.13	3.42	29.48
Negotiating the essential tension	0	0	2.85
Communal responsibility for individual growth	1.90	35.36	2.68

Percentage for each stage of formation is based on the total number of coded conversation excerpts, which differed for each school (151 in Doone and 146 in Crannog).

Dave: It is squares, they have four sides. That is all it is. That is where the word quadratic came from. I never realized that! I just thought, you know, it has two factors, two solutions or whatever and some of them –

Fiona: I often wondered!

Dave: Is it? Why is it 4? Because then you go cubic and then go cubed and that is a 3 and it all adds up and makes sense. Quadratic does not make sense, I've got that question. I've never known why before. I actually thought it was because, do you remember you showed me how you do squiggles, you split it quadratically, which is –.

Fiona: Four terms.

Dave: Four terms. I was wondering is it because actually underneath it is a four-term thing, but it is not. It is just simply because a square has four sides, so they are called a quadratics.

Fiona: So, it is a bit of a, nearly a kind of a misnomer, when you have to look at cubics and linears and others.

Dave: Or you can say it actually makes perfect sense, if you link back to the actual original starting point which is squared by squared.

Walter: Which is x-squared!

In this excerpt two of the most experienced teachers, Walter and Fiona, demonstrably valued this contribution from Dave and there was a sense of enjoyment and wonder in the group's conversation and work.

While teachers at Doone often had difficulty finding a time to meet, Crannog had a designated time in which all mathematics teachers were free and, therefore, had a specific weekly time in which they could collaborate. This incorporation of time for teachers to meet and converse seems to have impacted on their capacity to introduce and reflect on reforms in their teaching (Penuel et al., 2009; Takahashi and McDougal, 2016). Teachers in Crannog therefore had a comfort and ease with one another due to their familiarity working together, outlined further below. It is notable here, particularly in the Irish context, that the school with a wider variety of physical and temporal spaces for teachers to work was a fee-paying school.

4.2 The evolution of teacher community across cycles of lesson study

As noted above, both sites represent very different stages of formation of teacher community and, therefore, different examples of evolving teacher community within Lesson Study over multiple, successive cycles. The findings across both case studies suggest, however, that Lesson Study (1) does not weaken teacher community and (2) has the potential to contribute to the development of teacher community. The potential for Lesson Study to contribute to the development of teacher community was particularly evident in Doone, where the majority of features in teachers' dialogue were recorded at 'beginning' stage in Cycle 1 and at 'mature' stage in Cycle 4. It is important to highlight here that, although the percentage of codes shared here at a 'mature' stage was higher for Doone than for Crannog in their final cycle, this does not suggest that they were at a more mature stage of teacher community (see Table 4). The percentage of codes refers only to the percentage of sub-categories within that stage of evolution, coded in comparison to other categories in teachers' Lesson Study conversations within that cycle.

Similarly in Crannog, although the teacher community began their Lesson Study work at an already evolving, almost mature, stage of formation, participating in Lesson Study seemed to provide teachers with opportunity to strengthen elements of their professional, collaborative work across successive cycles (see Table 5).

The category of 'negotiating the essential tension' did not prominently feature in the evolution of teacher community across both case study sites (see Figures 1 and 2). The authors posit that this may be due to the fact that Lesson Study provided teachers with agreement over the purposes of their community, which was

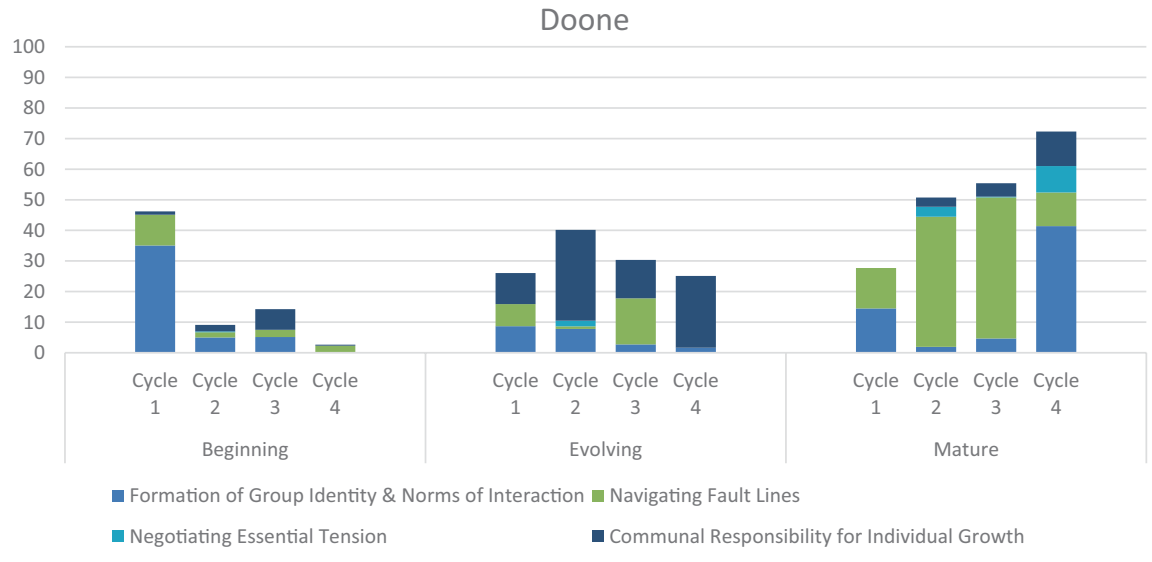

FIGURE 1
Categories of formation of teacher community across Cycles of Lesson Study at Doone (percentages given as total of coded excerpts within a cycle).

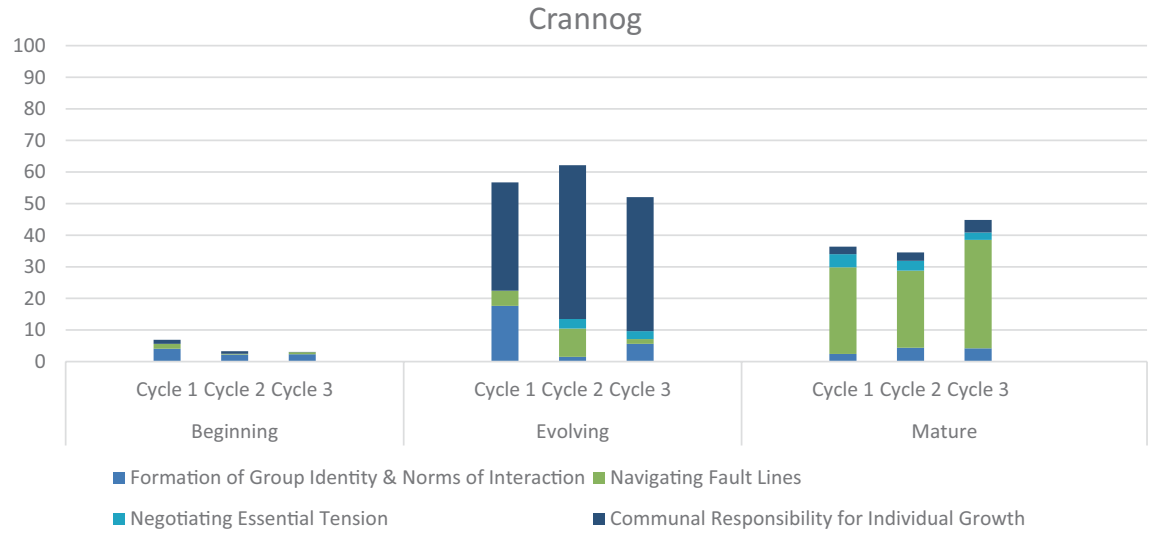

FIGURE 2
Categories of formation of teacher community across Cycles of Lesson Study at Crannog (percentages given as total of coded excerpts within a cycle).

to implement the new mathematics curriculum through planning Research Lessons. Establishing a 'shared vision' at the beginning of their participation in Lesson Study also precluded any opportunity to allow different people to pursue different activities, ensuring each group operated at an 'evolving' or 'mature' level for this category with everyone involved in the joint enterprise of planning one Research Lesson.

It is also important to note that, as it was not possible for all teachers to attend all meetings, this resulted in the presence of beginning and evolving features of 'formation of group identity and norms of interaction' in teachers' Lesson Study conversations. This was evident in elements of identification with subgroups and pseudocommunity when teachers, who were absent for particular decisions or conversations, came back to the group. This may be important in considering the make-up and facilitation of Lesson Study groups, where all members should endeavor to be present for meetings as much as possible.

4.3 Core features of evolution of teacher community in lesson study

4.3.1 Navigating fault lines

Aligning with the findings of Warwick et al. (2016), who highlight the challenging of ideas in Lesson Study as key to the dialogic process, we see that the category of 'navigating fault lines' was key to the evolution of the teacher communities on both case study sites. With an absence of any disagreement or conflict a teacher community can fail to make any progress (e.g., Rousseau, 2004). These elements of navigating fault lines, particularly the 'understanding and productive use of difference,' contributed significantly to the 'mature' nature of interactions for both groups.

The prevalence of 'navigating fault lines' at a mature stage of community was particularly evident in Crannog (see Figure 2) where, from the first cycle, teachers demonstrated an ease in communicating differences of opinion and utilizing this to build on ideas for their Research Lessons. The excerpt below illustrates such an interaction during teachers' discussions in their final Cycle at Crannog, where Elaine had suggested they focus the lesson on differentiation from first principles:

> Dave: Sorry, could you not do that? Because there's nothing more off-putting for fourth years.
> Elaine: Than first principles?
> Dave: Than first bloody principles. Could you go off and do some practical applications of it first?
> Fiona: Of rates of change?
> Dave: Yeah, distance versus times…
> Stephen: When they actually, probably, they understand it now and they actually enjoy it…
> Elaine: Yeah, and come next year, they'll be well able to talk about rates of change.

In her final interview, Fiona reflected on the group being able to express differences, articulating an awareness that differing opinions can lead to constructive ideas:

> "We might start off by saying 'we'll do this' and then somebody else would say 'oh we'll do this' and just by them talking it through then you'd think 'oh, I see, that's actually a better way to do it.' By them being kind of nearly convinced by someone explaining what their suggestion is." Fiona

While this group of teachers at Crannog were clearly comfortable working with one another, Lesson Study provided them with a structure within which they had opportunity to specifically focus on sharing ideas, methodologies, and approaches to their classroom practice. This allowed them to constructively build on or dispute one another's ideas through this shared dialogue.

Similarly in Doone, in the final cycle there were far more examples of teachers comfortably expressing differing ideas, i.e., 'navigating fault lines,' during their planning meetings. The conversation excerpt

below, from their final Lesson Study cycle, illustrates such an example where Lisa and Michael comfortably disagreed with Kate and the group agreed to extend the numerical examples given to students to incorporate more than whole numbers:

> Lisa: I don't know Kate. I think if we want to keep this flowing… the real nitty bit of this, which would be lesson three, which will be all the practical applications. Do you then just hang it on there? Because a practical application will only ever deal with whole numbers.
> Kate: Yeah, okay. Spread that out there?
> Michael: Yeah, no, I think if it's, if you are on about a triangle and the square root on the side and –.
> Kate: Just give a decimal.
> Michael: Yeah, you see, yeah.

In the initial cycles of Lesson Study at Doone (see Figure 1) there were far more examples of 'denial of difference' (beginning stage), where differing views or opinions were ignored or brushed aside, and 'appropriation of divergent views by dominant position' (evolving stage), often with Kate dictating what direction the group would take without looking for consensus. Such examples suggest that there was an unequal power distribution within the group (Corcoran, 2011). There were also few examples of discussion of differing opinions in the first three cycles at Doone, perhaps due to teachers' unfamiliarity in working with one another in this way (Rousseau, 2004), something which had to evolve over time. It is important to re-emphasize that three of the participating teachers at Doone identified themselves in their initial interviews as 'out-of-field' teachers (Ní Ríordáin and Hannigan, 2011), potentially impacting on their confidence to dispute or challenge ideas and therefore avoiding conflict. In addition, teachers at Doone did not offer as much critical reflection on their group dynamics in their individual interviews as teachers at Crannog, perhaps demonstrating a level of familiarity yet to be achieved within the group. This finding may point toward a potential area for facilitators of Lesson Study to focus on during their work with teachers, ensuring differences in ideas and opinions are aired and not swept aside.

It may also be important to highlight that in navigating fault lines humor played a prominent role in teacher communities in both schools, something also highlighted by Clivaz et al. (2023) in their work investigating knowledge building in Lesson Study. In her final interview Fiona in Crannog noted that, where there were differences in opinion, she felt any comments that could have been taken as critical or negative were accepted in good spirit, due to the nature of the group and their sense of comfort working together.

> "I think you need to be able to…take comments whether they are meant in jest or partially in jest. You know, when you say things the odd time and, okay, they are said jokingly but there's an element of truth in them. I think, just, I think we probably know each other well enough at this stage to be able to do that which helps." (Fiona)

This element of humor in navigating potential fault lines, which was also visible in the use of expletives (as in the example from Doone below) or sarcastic reference (as in the example from Crannog above), may well be a necessary cultural element (Stigler and Hiebert, 2016) of adopting Lesson Study in school-based settings in Ireland.

4.3.2 Communal responsibility for individual growth

Another core category in the evolution of teacher community at both sites was a 'communal responsibility for individual growth.' Within this category our data points toward the importance of teachers recognizing that colleagues can be resources for one's learning (evolving stage) and a visible commitment to colleagues' growth (mature stage). The emergence of these features was most noticeable within the conversations of teachers at Doone, where there was increasing recognition that colleagues could be an important resource for one's learning over the cycles of Lesson Study (see Figure 1). Examples of colleagues openly commending one another's practice to nurture their colleague's confidence were particularly striking within the Lesson Study conversations at Doone as they matured to a more 'evolving' stage of teacher community. We highlight such an example within Cycle 2 where Owen, as a newly qualified and out-of-field teacher, openly states his feelings of uncertainty and is explicitly supported by his colleagues. Kate and Lisa admit to him that none of them are teaching in a way that they know they should and that they are using Lesson Study as their 'Alice in Wonderland' moment to develop better ways of teaching.

> Owen: I am, like I don't know, I am just questioning my teaching right now.
> Lisa: Listen, can I just say to you –.
> Kate: None of us teach it like this.
> Lisa: None of us teach it like this!
> Kate: I do half the time "top by top and bottom by bottom, you are a [expletive] if you do not get it, you [expletive] thick!"
> Owen: "And do not talk…I do not care whether you know it or not!"
> Lisa: Listen, this is the ideal world… let's just live in the Alice in Wonderland moment…

In another example of 'commitment to colleague's growth' teachers at Doone commended Michael, another out-of-field teacher, in their final Cycle of Lesson Study.

> Lisa: What I was going to say, Michael, those problems were excellent that you put together.
> Owen: Yeah.
> Lisa: You know? Really good! And the one I liked best – can I just see that for a second? Was Rory McIlroy, the map of America (laughing).

Similarly, these features of recognizing colleagues as resources for learning and being committed to colleagues' growth were specifically highlighted by Dave in Crannog in his final interview reflecting on their Lesson Study work, specifically noting the often-individual nature of teaching in Ireland (Moynihan and O'Donovan, 2022).

> "We are not used in this country, I would say generally, to having other adults and teachers in our room, so that could be a difficult step for some people. We are a fairly comfortable department

> maybe more recently, because we have had to talk about our teaching and our successes and our failures – we have had to help each other out so you have to be willing to say 'I'm no good at this' or 'I'm weak at this' or 'You're good at this, can I have help?' It was my first time ever seeing Fiona teach, it was my first time ever seeing Elaine teach so, em, you trust other people's contribution to the preparation process. You begin to realize that the way I would always have done this might not necessarily be the best way." (Dave)

These examples demonstrate, we believe, a number of the key features of teacher community that assumes responsibility for the maturation of the group. We see that having the opportunity and trust to question one's own practice and pedagogical approaches within Lesson Study affords instances to colleagues to support one another, and such positive reinforcement provides a further step to aiding the maturation of the community. Strengthening of the teacher community can occur through the communal celebration of successes and the honest analysis of failures, something which is facilitated through the planning and post-lesson discussions within a Lesson Study cycle (Figure 2).

5 Discussion and conclusion

In this paper we provide insight into how Lesson Study has the potential to strengthen and develop teacher community. This research contributes to the literature by providing an in-depth analysis of qualitative data generated during the participation of mathematics teachers in Lesson Study in two schools over the course of one academic year, utilizing Grossman et al.'s (2001) framework for the formation of teacher community. The research highlights that different groups of teachers may begin their Lesson Study work at different stages of evolution of teacher community, thereby impacting their ability to meaningfully interact and collaborate. The research also provides evidence that Lesson Study has the potential to strengthen and develop teacher community over successive cycles, further highlighting the positive impact of this form of professional development on school communities. Finally, the research identifies core elements of teachers' Lesson Study conversations necessary to the maturation of teacher community, namely engaging with conflict, effectively navigating disagreements, and explicitly recognizing colleagues as uniquely placed to inform one another's learning.

In our findings there were striking differences between the two groups of teachers in relation to their stages of development as a teacher community during their initial engagement in Lesson Study. This may partly be attributed to school context, related to spatial and temporal provisions for collaborative work. At Crannog school leadership provided teachers with allocated, shared time for the subject department to meet, teachers had a designated subject space within the school and a designated work area for teachers, positively impacting teachers' collaborations (Penuel et al., 2009; Takahashi and McDougal, 2016; Heckathorn and Dotger, 2022). It may be relevant to note here that the fee-paying status of this school may have allowed the school to provide additional physical space for teachers to work, something which is absent from most non fee-paying schools in Ireland. Teachers at Crannog had already established a familiarity and trust with one another, where they were happy to recognize each other's unique contributions and learn from one another. While there were teachers of varying years of experience at the school, there was an apparent equity of power distribution in teachers' interactions with each other (Corcoran, 2011). The experience was different at Doone, however, as teachers did not have the same professional temporal or spatial collaborative opportunities, again highlighting the important role of school leaders in facilitating teachers' participation in collaborative professional development (Takahashi and McDougal, 2016; Heckathorn and Dotger, 2022; Moynihan and O'Donovan, 2022). The early stage of evolution of this teacher community may also have been impacted by some of the participating teachers identifying as out-of-field, therefore affecting their self-efficacy in terms of their mathematics pedagogy. This may have contributed to their tendency to shy away from offering opinions or articulating differing ideas to colleagues, leading to the cumulative talk apparent in their initial cycles of Lesson Study (Vermunt et al., 2023). There were also noticeable conflicts in power distribution in conversations at Doone, which may have impacted elements of navigating fault lines appearing as disputational talk (Grossman et al., 2001; Corcoran, 2011; Vermunt et al., 2023). These findings suggest that in cases where Lesson Study has not demonstrated impact on teachers' knowledge or practices (e.g., Bjuland and Mosvold, 2015) there may be a link to underdeveloped teacher community and further research should be undertaken in this regard.

While colleagues have added to our knowledge of Lesson Study interactions by highlighting aspects of teacher dialogue in knowledge building (Warwick et al., 2016; Vrikki et al., 2017; Clivaz et al., 2023; Vermunt et al., 2023), in this research we have highlighted key elements of teachers' interactions in developing teacher community within Lesson Study. These findings may be particularly relevant since, in this research, exploratory dialogue associated with teacher learning (Vermunt et al., 2023) seems more associated with evolving and mature stages of teacher community. Warwick et al. (2016) defined 'supportive moves' as core to teachers' dialogue within Lesson Study, highlighting examples where one teacher raised an idea and others built on the initial idea while illustrating their own observations. They pointed to how such moves allowed the cumulative building of ideas, which led toward agreement on pedagogic development (Warwick et al., 2016) and we found evidence of such talk in teachers' conversations as they matured as a community. Fernández (2010) also outlined the importance of teachers feeling comfortable to contribute ideas and raise alternative perspectives. This form of exploratory talk, where teachers make their implicit thoughts explicit (Fujii, 2018), allows for inter-thinking, which may also necessitate respectful disagreement (Warwick et al., 2016; Vermunt et al., 2023), as further highlighted within our study.

Within our data we identified key features of maturation of teacher community within Lesson Study toward these latter stages, specifically 'navigating fault lines' and 'communal responsibility for individual growth.' These findings contribute to the literature in refining our understanding of strengthening of teacher communities within Lesson Study. Furthermore, the results point to specific elements which facilitators of Lesson Study may wish to focus on within teachers' conversations in order to support them through their initial engagements with this model of professional development. As outlined by Warwick et al. (2016), facilitators should be trained to encourage teachers to both share and receive appropriately phrased challenges from their colleagues. In this

regard, it may be important for facilitators to ensure that there is no denial of differences in opinions or ideas expressed within planning or reflection meetings. Similarly, it may be important for facilitators to ensure that there is no appropriation of divergent views by a dominant position (Lewis J. M., 2016; Clivaz et al., 2023). As well as ensuring communal responsibility for the work involved in a cycle of Lesson Study, it may also be important that facilitators highlight moments where teachers can recognize the value of learning from colleagues within their Lesson Study conversations. Further research on the role of the facilitator in specifically supporting teachers through the evolution of their teacher community within Lesson Study would be of interest. Furthermore, the development of teacher community in groups conducting Lesson Study without regular, explicit input from a facilitator would also be of interest.

This research highlights the potential of Lesson Study in the Irish STEM Education environment, aligning with policy objectives of collaborative teacher education to build teacher capacity in schools and emphasizing mathematics as underpinning all STEM subjects (Department of Education, 2017; 2022). This research suggests that Lesson Study is likely a viable model to support the development of teacher community in the long term and may provide a useful option for school leaders and policymakers to deliberately support the cultivation of teacher collaboration in learning communities for sustainable professional development. We hope this research contributes to our understanding of Lesson Study and adds to the body of work around reforming educational cultures where teaching can often be considered as isolated and isolating work.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://www.maynoothuniversity.ie/iqda.

Ethics statement

The studies involving humans were approved by the Ethics Committee, School of Education, Trinity College Dublin. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AN: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. EO: Formal analysis, Visualization, Writing – review & editing. AS: Conceptualization, Methodology, Supervision, Writing – review & editing. DH: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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