

Exploring online lesson study as a vehicle for teacher collaborative professional learning

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179

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Abstract

Purpose – This paper presents emerging findings from an ongoing research project which aimed to explore online lesson study (OLS) as a vehicle for teacher collaborative professional learning.

Design/methodology/approach – Two parallel OLS cycles with two OLS teams were facilitated by the author using Zoom and Google Drive as digital collaborative tools. Each OLS team comprised three primary teachers who taught in three different schools, with both teams' research lessons taking cross-curricular science, technology, engineering and maths (STEM) focus. In order to explore the influence of OLS on teachers' collaborative professional learning outcomes in STEM, a qualitative case study approach was adopted, with data drawn and thematically analysed from OLS meeting transcripts, semi-structured interviews with teachers and the author's reflective diary. Boundary crossing is used as a theoretical lens to ascertain the potential of OLS as a vehicle for teacher collaborative professional learning.

Findings – Findings suggest that OLS facilitated collaborative learning and positively contributed to teacher participants' co-construction of knowledge in relation to STEM teaching approaches.

Originality/value – The study described in this paper represents the first OLS conducted in the Irish context and also represents the first inter-school lesson study (LS) conducted in the Irish primary context.

Keywords Online lesson study, Boundary crossing, Teacher knowledge, Teacher professional development, Digital technology, STEM

Paper type Research paper

Introduction

Lesson study (LS) describes a model of collaborative teacher Professional Development (PD) where a group of teachers come together to identify, research, plan, teach, observe and reflect on a research lesson with a group of learners (Lewis *et al.*, 2006), a process typically facilitated by an external subject expert or Knowledgeable Other (KO) (Takahashi, 2013). Whilst the model originated over one hundred years ago in Japan (Makinae, 2019), it has since been adapted and contextualised by practitioners across the globe (Gyori, 2019; Seleznyov, 2018). Murata (2011) suggests that such modifications to LS are “expected and essential” (p. 10) due to the localised and contextualised nature of teaching practice. More recently, the LS model has been adapted to be delivered in online environments (Huang *et al.*, 2021). Whilst broader

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supportive conditions need to be in place in order to operate sustainably (Wolthuis *et al.*, 2021), face-to-face LS has been credited with enabling teachers to collaborate (Vermunt *et al.*, 2019) and cross boundaries of practice to co-construct knowledge (Dudley *et al.*, 2019; Wake and Seleznyov, 2020), thus overcoming the relative isolation they can often experience in their professional work (Flanagan, 2022). However, given its relative novelty, much less is known about the effectiveness of online LS (OLS) (Huang *et al.*, 2021). Lewis (2009) suggests LS creates multiple pathways for learning that lead to instructional improvement, with each of these pathways representing boundary crossing opportunities. Pathways include increased knowledge of subject matter (Bae *et al.*, 2016; Dudley *et al.*, 2019) and of pedagogical strategies (Dudley *et al.*, 2019; Schipper *et al.*, 2018). However, it remains unclear whether these LS pathways for boundary crossing translate when LS conducted online (Huang *et al.*, 2021). Moving LS online may offer new boundary crossing opportunities. It has been suggested that OLS enriches opportunities for teacher collaborative learning in ways not possible through traditional face-to-face LS (Calleja and Camilleri, 2021), for example, capturing, creating and sharing knowledge efficiently in real time using collaborative digital tools such as Google Drive (Weaver *et al.*, 2021). Findings from recent studies on OLS (e.g. Calleja and Camilleri, 2021; Huang *et al.*, 2021) have called for further research in order to deepen understanding of the various affordances of OLS as a PD approach. This paper aims to respond to this call, by sharing empirical qualitative insights from a small-scale project titled “STEMunities”, the overall aim of which was to explore the potential of OLS as vehicle for teacher collaborative professional learning in science, technology, engineering and maths (STEM) in the Irish primary education context. The STEMunities project involved an innovative inter-school OLS initiative, facilitated by the author, where they served as facilitator and KO, with an existing inter-school partnership, consisting of three Irish primary schools, who had chosen a STEM curricular focus. The STEMunities project was guided by the following research question: Does OLS facilitate teacher collaborative professional learning in STEM? This paper focusses on aspects of the study related to teachers’ learning outcomes related to their knowledge about teaching STEM specifically.

STEM knowledge for teaching

Integrated Science, Technology, Engineering and Mathematics, or STEM education describes an approach to teaching the content and skills from two or more STEM domains within an authentic real-world context to enhance student learning (Kelley and Knowles, 2016). It has been maintained in recent STEM education literature (e.g. Hourigan *et al.*, 2021; Lertdechapat and Faikhamta, 2021) that integration of multiple subject areas, as in the case of STEM, requires teacher knowledge which comprises a number of domains. This paper focuses on the domain of knowledge about teaching, which pertains to teachers’ capacity to operationalise their own STEM content knowledge to link curricular content and skills related to STEM activities. STEM knowledge about teaching also extends to teachers’ knowledge of how to design appropriate STEM learning experiences, using a range of appropriate and adaptive instructional strategies in order to meet the needs of their students (Hourigan *et al.*, 2021; Lertdechapat and Faikhamta, 2021). In terms of how changes in teachers’ knowledge can be identified, Bae *et al.* (2016) developed a coding tool to examine discussions between teachers during LS. The purpose of their tool was to identify instances where changes in knowledge were demonstrated during such discussions. Their findings indicated a high frequency of pedagogy codes that captured deep discussions of teaching, specifically in terms of teachers discussing pedagogical ideas and teachers describing their rationale for selecting a particular pedagogical approach. Whilst Bae *et al.*’s (2016) tool was focused on Science specifically, the coding tool can also be applied to the domain of knowledge about STEM teaching.

Collaborative learning in LS as boundary crossing

In order to support learning and development of such knowledge, it holds that teacher PD needs to be ongoing, collaborative and contextualised (McMillan and Jess, 2021). Contemporary transformative models of PD are characterised as a process of problem-identification by professionals and subsequent activity, “where the subsequent activity involves enquiring into one’s own practice and understanding more about other practice” (Kennedy, 2014, p. 7)- as in the case of LS. Akkerman and Bakker (2011) claim that all learning involves boundary crossing, which they describe as “a sociocultural difference leading to discontinuity in action or interaction” (p. 133). They point out that the identified discontinuities do not need to be overcome in order for learning to occur. Instead, learning results in a renewed sense making of different practices. In order to effectively engage in boundary crossing which leads to new learning, collaborative teacher PD activities should be coherent, relevant and of sufficient duration to allow teachers to make sense of and contextualise new learning (Kennedy, 2011). Boundaries within the STEMunities study were complex and multilevel (Akkerman and Bruining, 2016), in that they were institutional (between school sites), interpersonal (between teachers) and intrapersonal (within teachers themselves). Through engaging in OLS, were invited to these multilevel boundaries in order to interact and engage with new knowledge and practices in relation to STEM.

Encounters at boundaries of practice are associated with risk, due to potential conflict between different practices and ways of thinking, but are also associated with growth, as is the case when a boundary is crossed in order to engage in new learning (Wake and Seleznyov, 2020). Whilst Akkerman and Bakker (2011) articulate a number of learning mechanisms associated with boundary crossing, of particular interest to the present study is the learning mechanism of transformation. Akkerman and Bakker describe transformation as a mechanism which can lead to profound changes in practices and the creation of novel “boundary practice” (p. 146) and suggest that it comprises four learning processes. Firstly, transformation requires a process of confrontation to occur, where a problem is jointly recognised, for example, students’ difficulty in grasping a particular concept in mathematics, which compels individuals to reconsider their existing practice. Within LS, this can occur during the identification of the LS group’s overarching goal and subsequent formulation of their research question. The second process involved in transformation is recognition of a shared problem space, in response to the confrontation. This shared problem space is cultivated during the research and planning phase of LS, where teachers have the opportunity to engage with new ideas and practices in response to their identified research question. Within the problem space, the third process of hybridisation can occur. This involves the melding of ideas and practices from different individuals in response to the identified problem in order to create a new practice. In LS, this occurs when teachers collectively make and justify decisions on what learning activities to include in their research lesson plan. The fourth and final process involves the process of crystallisation, where new routines or procedures are enacted which embody what has been created or learnt. This occurs during the teach, observe and reflect phases on LS, where teachers have the opportunity to conduct their live lesson with their students and subsequently reflect on how well the lesson addressed their research question and their original overarching goal. Teachers also have the opportunity to reflect on how they might apply the overall learning from engaging in LS to their future practice.

Star and Griesemer (1989) suggest the term “boundary object” as a tool which enables boundary encounters and supports establishment of shared meaning and co-construction of knowledge across a boundary. In the context of the STEMunities project, the OLS facilitated by the author as KO, along with the digital tools (Zoom and Google Drive) used to support interaction represented the boundary object. Previous research (e.g. Dudley *et al.*, 2019; Vermunt *et al.*, 2019; Wake and Seleznyov, 2020) have established that face-to-face LS can

serve as a boundary object by enabling dialogic discussions which contribute to teachers' learning outcomes. [Warwick et al. \(2016\)](#) describe learning outcomes as expressed changes in knowledge or future pedagogic intentions linked to their LS experiences, representing an example of boundary crossing. More specifically, instances where teachers make statements about how as a result of engaging in LS, their thinking has changed or that they plan to make changes to their future practice ([Dudley and Vrikki, 2019](#)). This extends to the domain of teacher knowledge required to engage in effective STEM teaching as earlier described. With this in mind, the author was particularly interested in exploring whether similar learning outcomes could be achieved in an LS conducted online.

Digital boundary objects

Given the focus of the STEMunities project on OLS, how boundary crossing and collaborative learning outcomes may be mediated within a virtual environment merits consideration. It has been suggested that digital tools can support dialogue ([Mercer et al., 2019](#)) and collaborative generation of knowledge ([Hakkarainen, 2009](#)), by aiding the process of boundary crossing and helping to make different perspectives explicit within the group of learners. [Pifarré \(2019\)](#) suggests that digital technologies can allow co-constructed artefacts such as lesson plans and teaching resources to be saved, revisited, modified or repurposed at a later time. Thus, these digital artefacts can make learning trajectories more visible, which can help knowledge, to progress and develop over time. Considering characteristics of effective online PD specifically, [Yurkofsky et al. \(2019\)](#) suggest that PD approaches should ensure teachers' thoughtful and sustained engagement; be flexible and embedded in practice; enable teachers to experience meaningful interactions and aid teachers to reflect on their own practice by engaging in discussions that challenge existing beliefs as well as create new understandings.

Research context

The OLS project described in this paper was facilitated by the author, in their capacity as a primary STEM PD facilitator working with a national government-funded support service in Ireland. Whilst the author had previous experience facilitating traditional face-to-face LS, the project represented their first experience facilitating OLS, which took place within the unique context of a pre-existing Shared Education (SE) partnership. This consisted of three primary schools, Broc*, Eala* and Spideog* (*pseudonyms). SE is a peace-building contact-initiative programme, funded by the European Union, which aims to enable teachers, students and schools from different cultural and religious backgrounds to work in partnership and engage in collaborative learning experiences with a curricular focus ([Gallagher, 2016](#)). However, in line with literature pertaining to SE partnerships (e.g. [Gallagher, 2016](#)) teachers and school principals in the three participating schools, who had chosen a STEM curricular focus, reported that the majority of their interactions to date had focused on pupil contact activities and teacher cooperation, rather than teachers' collaborative learning. Part of their rationale for agreeing to take part in the OLS was to explore its potential for enhancing professional collaboration and sharing of knowledge between teachers in each of the schools. Given that the partnership was already established, some of these teachers knew each other by name, but for others, the OLS was their first time to meet. All teachers had prior experience in engaging in STEM teaching within their own school context, held similar levels of general teaching experience and all taught the same grade level, with students aged 11–12 years. Given the unique context of the study and that sensitive data may be traceable, teachers are referred to by their school and OLS team throughout the paper. Limited information is given on individual teachers involved in the study to protect their identities.

Methodology

Following receipt of ethical approval and informed consent from relevant stakeholders, the author facilitated two parallel OLS cycles virtually over a six-month period. Six teacher participants took part, arranged into two OLS teams of three, who participated in one OLS cycle each. Both teams' research lessons took a cross-curricular STEM focus. Each team decided on their own overarching goal, specific area of focus and research question for their OLS. Team 1 chose to explore how their research lesson could develop students' experimentation and communication skills using Lego WeDo® robotics kits. Team 2's research question sought to explore how their research lesson could support students' development of communication and oral language skills, through an inquiry focused on gender stereotyping in STEM. OLS meetings and activities took place fortnightly via Zoom, in line with the following schedule:

- (1) Meeting 1. *Identify* overarching goal
- (2) Meeting 2–3. *Research*: Journal Club; examination of curriculum documents; resource identification, sharing and critique; decide on research question
- (3) Meeting 4–6. *Plan*: Devise research lesson plan; agree on resources and planned sequence of learning activities; design observation schedule
- (4) Meeting 7*. *Observe* research lesson video using observation schedule (*offline).
- (5) Meeting 8. *Reflect*: Collective reflection on research lesson using uploaded completed observation and pupil work samples.

Each 60–90 min meeting was recorded and transcribed verbatim by the author. A STEMunities OLS booklet (Holden, 2020) was designed by the author based on the work of Dudley (2011) and Ní Shúilleabháin and Professional Development Service for Teachers (2018), which guided the process by providing a step-by-step guide and prompt questions for each phase of the OLS (Bielaczyc, 2006). A shared Google Drive folder was utilised to enable participants to engage with, create and share various LS materials such as relevant research articles for their journal club, curriculum documents, teaching and learning resources and lesson planning documents and lesson observation schedule. The identify, research and plan phases took place during pandemic-related school closures so teachers joined in these meetings from their own homes. At the end of each meeting, participants were encouraged to reflect on their learning and given time to draft a reflective diary entry based on the meeting. Schools subsequently reopened, which allowed each of the teachers to teach and video record their research lesson face-to-face with students in their classrooms between meeting 6 and 7 as earlier listed. In line with current Irish legislation pertaining to Child Protection and General Data Protection Regulations (GDPR), teachers were not permitted to play back videos for persons outside of their own school. Instead, each teacher used the allocated meeting time during the observe phase of the OLS to individually self-review their research lesson video and used their collaboratively planned observation schedules to aid observation and critical reflection. The completed observation schedules were then uploaded to the Google Drive folder and discussed by each group when they reconvened on Zoom for their post-lesson meeting reflection meeting. Each group engaged in one post-LS reflection meeting which was facilitated via Zoom. Following the OLS, each team drew on their reflective diary entries which they had maintained throughout the OLS in order to create a Shared Learning poster. The purpose of these posters was to enable teachers to share the learning from the OLS with their colleagues and wider school communities, by providing an overview of their research lesson along with their own professional insights and learnings.

Given the author's direct involvement in the STEMunities project as designer, researcher, facilitator and KO, this created a considerable risk of bias in terms of reporting on findings (Greene, 2014). In order to address this risk, the author maintained a reflective diary throughout the project from initial planning stages, as well as during data gathering and analysis phases. This diary served as an audit trail (Merriam, 1998) and enabled the author to articulate the role they played in the OLS along with the rationale underpinning the actions and choices they took, thus enhancing the rigour and transparency of the research process and trustworthiness of findings (Greene, 2014). The diary also enabled critical reflection (Brookfield, 2017) for the author as they moved from their established face-to-face LS practice into the online space for the first time, which is discussed in further detail in Holden (in-press).

A qualitative case study approach (Yin, 2003) was adopted in order to address the research question, which sought to explore OLS as a vehicle for teacher collaborative professional learning, with two OLS teams serving as a collective case. Rather than seeking to generalise, the purpose of the case study was to particularise by providing rich, thick descriptions of the unique research situation (Merriam, 1998), in order to provide readers with sufficient detail to determine for themselves if and what aspects of the study findings could be applied elsewhere. Data were gathered from OLS meeting recordings and post-OLS individual semi-structured interviews via Zoom (See Appendix for Interview Schedule), which were conducted, recorded and transcribed verbatim by the author to ascertain teachers' individual perceptions of OLS as a vehicle for collaborative professional learning.

The study described in this paper was conducted in line with a pragmatic assumption, according to which, reality is multifaceted and constructed subjectively (Hammond, 2013). Therefore, reliability in the context of the study related to the way the author aimed to describe and explain the world as those within that world, i.e. the teacher participants, experienced it. In order to enhance reliability, the author employed triangulation which comprised multiple methods of data collection (OLS meeting transcripts, post-OLS interviews and a reflective diary). Reliability was also ensured through the use of an audit trail (Merriam, 1998), which in this instance pertained to the way in which the author's position and justification for decisions during the research process, along with a thorough detailed account of the approach to data collection and analyses were articulated.

Data analysis

Data analysis was undertaken using Braun and Clarke's (2006) six-step Thematic Analysis (TA) approach, which comprised: 1. Familiarisation with data; 2. Generation of initial codes; 3. Identification of themes; 4. Review of themes; 5. Definition and naming of themes; and 6. Production of a narrative report. In line with Braun and Clarke (2021), analysis was conducted in two phases with a deductive thematic analysis was undertaken initially using an *a priori* coding tool to identify semantic (explicit) codes. This was followed by a subsequent inductive sweep on the same OLS meeting and interview data identify other notable themes which may not have been identified using the coding tool. This two-phase analysis aligned with the qualitative pragmatic approach taken by the author, according to which, different perspectives provide different forms of knowledge about a phenomenon so that, together, they produce a broader understanding (Hesse-Biber and Johnson, 2015). This two-phase approach enhanced the validity of findings and minimised the risk of confirmation bias and over-categorisation of data (Morse and Mitcham, 2002).

The familiarisation step involved the author re-reading OLS meeting and interview transcripts line-by-line. This also supported the author to transition from the role of OLS facilitator and KO to the role of researcher (Greene, 2014). OLS meeting transcripts were then divided into units of analysis, defined as statements by participants. Interview transcripts were divided into units of analysis defined as a participant's response to a question or

follow-on question. Transcripts were then imported to NVivo software to enable identification, coding and review of instances of teacher learning outcomes within the meeting and interview transcripts using a STEMKT coding tool, based on [Bae et al. \(2016\)](#). Given that changes in teacher knowledge, i.e. teacher learning, represent instances of boundary crossing, the coding tool in [Table 1](#) also explicitly shows how indicators of development of knowledge about teaching STEM map to particular boundary crossing learning processes as earlier discussed.

This tool also provided *a priori* themes in relation to step five of [Braun and Clarke's \(2006\)](#) TA approach. The STEMKT coding tool enabled deductive identification of instances where teachers expressed changes in knowledge ([Bae et al., 2016](#)) or future pedagogic intentions linked to their OLS experiences ([Warwick et al., 2016](#)). More specifically, instances where teachers made statements about how as a result of engaging in OLS, their thinking has changed or that they planned to make changes to their future practice ([Dudley and Vrikki, 2019](#)). In response to the research question, results from each phase of thematic analysis were then converged ([Creswell and Plano Clark, 2011](#)), in order to identify the influence (if any) of OLS on teachers' collaborative professional learning in STEM.

Findings

In terms of learning outcomes, findings from analyses implied that teachers' learning was focused on broader pedagogical matters, centring on teaching methods, with somewhat limited evidence of specific STEM content knowledge development.

Analysis of data revealed that teachers gained a variety of insights in relation to methods for effective STEM teaching. These insights centred around making more informed choices in relation to teaching and learning resources which maximised inclusion of all learners. For example, one of the teachers in Group 1 commented on the low-threshold high-ceiling nature of Lego® as a STEM resource, *"By its nature, it [Lego] appeals to all of them [the students]. They're so engaged in it though, that's what I find. And even your maybe less academic students get the opportunity to succeed, it levels the playing field a bit, I think"*. (Team 1, reflection meeting). Teachers' knowledge in relation to effective STEM teaching derived from conversations and sharing of ideas within each of the OLS teams. For example, in line with their overarching goal, during the research phase of the OLS, Team 2 read and discussed a research article about techniques for fostering student dialogue, they then discussed these in relation to their students' needs and subsequently factored these techniques into their research lesson.

During the OLS, teachers gleaned new understanding in relation to adopting less didactic approaches in the context of STEM pedagogy. Teachers noted the importance of inquiry-based pedagogies in STEM, facilitating students to uncover learning for themselves, rather than taking approaches where the teacher is the sole provider of knowledge. This was summed up by a teacher in Team 2, who remarked during their post-lesson reflection meeting, *"As teachers, we need to pause before we spill all the beans, they [the students] do t learn as much if we hand it all over"* (Team 2, reflection meeting). Facilitation of student discussion and minimisation of teacher talk in order to promote students' critical thinking was highlighted by both OLS teams. For example, during their post-OLS interview, one of the teachers from Broc commented on new insights deriving from their OLS engagement which held relevance for their future teaching *"Now I really realise that the students need to be able to figure it out for themselves. We drop the crumbs so that they will come and follow"*. (Post-OLS interview). Teachers in both teams also recognised that whilst inquiry-based approaches formed the majority of pedagogical approaches drawn upon during their research lessons, they also recognised that teacher input, guidance and instruction was also required at certain

Knowledge domain	Code	Description	Indicator	Boundary crossing transformation learning processes
Knowledge of teaching STEM	[T1]	Knowledge of methods for effective STEM teaching	Teacher/s <ul style="list-style-type: none">• Mentioning or describing a pedagogical strategy or approach to each other (e.g. Think-Pair-Share)• Admitting to or showing evidence of becoming aware of a new pedagogical strategy/ approach or describing a change in their own pedagogical knowledge	Confrontation: Problem is jointly recognised which forces individuals to reconsider their existing practice Recognition of a shared problem space
	[T2]	Understanding of level of appropriateness of teaching methods and activities	Teacher/s <ul style="list-style-type: none">• Debating or grappling with how a pedagogical strategy or approach should be used (e.g. comparing different tools, adapting existing tools)• Describing their rationale or justification for selecting a particular pedagogical strategy or approach	Hybridisation: Melding of ideas and practices from different individuals in response to the identified problem in order to create a new practice Crystallisation: New routines or procedures are enacted which embody what has been created or learnt
	[T3]	STEM content knowledge of individual STEM disciplines	Teacher/s <ul style="list-style-type: none">• Talking about STEM content knowledge. E.g. mentioning topics (e.g. surface area) or mentioning science, mathematics, engineering or technology content in a general way• Explaining STEM content to one another other. E.g. one teacher explaining a STEM concept to the rest of the group, or the whole group explaining STEM concepts collaboratively• Engaging in a debate or argument about STEM content, grappling with a STEM idea, but not necessarily coming to any conclusion• Admitting to or showing evidence of becoming aware of either a gap in their STEM content knowledge and/or a change in their STEM understanding• Describing their rationale or justification for selecting a specific STEM content or topic to examine more deeply• Discussing using outside resources (reading articles, consulting national standards, contacting an expert, etc.) to deepen their STEM content knowledge	Hybridisation: Melding of ideas and practices from different individuals in response to the identified problem in order to create a new practice

Table 1.
STEMKT coding tool **Note(s):** Adapted from [Bae et al. \(2016\)](#)

points, particularly if students were getting bogged down in a task. “*Yeah it might require a little bit of just maybe instruction on the coding part.*” (Team 1, reflection meeting).

Analysis of data revealed that teachers also gleaned significant insights arising from their engagement in the OLS, which stretched beyond the STEM subjects. During their research lesson planning meetings, teachers noted the importance of incorporating adaptive teaching approaches in STEM into their research lesson in order to meet students where they are at. They recognised the challenge of collaboratively planning a lesson which also took account of the diversity of student needs in each of their individual classes. “*Going back to what we were saying about pitching it at the right level . . . that’s very much organic. Our lessons will have to . . . move with the class that you have in front of you, and that will decide where you’re going to go next.*” (Team 2, Journal Club meeting). Teachers gleaned a fresh appreciation of socio-constructivist teaching and learning approaches, where children have the opportunity to learn from one another, with the role of teacher as facilitator, rather than as sole provider of knowledge. Teachers in both teams commented on how engaging in review of the research lesson gave them pause for thought regarding how little opportunity they gave their students had to engage in talk with their peers. Teachers indicated that the facilitation of discussion was something they planned to build into their future lessons. “*That’s something that I don’t often do. I just take their answers, rather than giving them a chance to discuss it first, so that’s something that I would do from now on.*” (Team 1, reflection meeting).

Findings revealed somewhat limited evidence of specific STEM content knowledge development amongst the teachers who took part in the OLS. Teachers did remark on how their use of Google collaborative tools during the OLS had worked effectively and efficiently to support their professional collaboration. On their use of technology during the LS, one of the teachers from Eala remarked during their post-OLS interview, “*I really developed my use of ICT for collaborative working with other teachers . . . just using [Google] docs for the sharing, with all of us on the same document. I had never used it in the way before.*”

Teachers utilised evidence from their research lesson to support their insights and the new knowledge they had acquired. For example, in relation to how they facilitated student discussions during lessons, one teacher from Team 1 remarked “*It was nice [during the research lesson] to have the kids’ ideas up on the board . . . By having it all up on the board, they could just look up and talk about it.*” (Team 1, reflection meeting). In relation to the OLS, the teachers noted that the opportunity to self-review the video of the research lesson allowed them to examine student learning in close detail. “*If I hadn’t been recording them, I wouldn’t have known there was that kind of discussion going on . . . it wasn’t obvious when you were walking around the classroom that there was a big discussion going on, it was only when I listened back to the recording that I heard it.*” (Team 2, reflection meeting).

Discussion

In line with the theoretical framework underpinning the study, learning outcomes were conceptualised as instances of boundary crossing. This boundary crossing pertained to instances where the participants demonstrated a change in their individual knowledge or ideas arising from their participation in the OLS, for example, acquisition of a new teaching strategy gleaned from a research article they had engaged with during the research phase. Boundary crossing was also characterised by instances where a participants demonstrated new knowledge or ideas which derived from another teacher within the group. For example, where a participant stated that they tried out an idea or strategy suggested by another member of the OLS team. Findings revealed that teachers engaged in boundary crossing opportunities during each phase of the OLS cycle. However, it is perhaps unsurprising that the majority of learning insights took place during the teams’ post OLS reflection meetings,

given that during post-LS reflection meetings, the perspectives and overall learning derived from throughout the LS process converge and are made explicit (Uffen *et al.*, 2021).

Whilst strong evidence was identified of certain learning outcomes being well-developed by the teachers as a result of engaging in the OLS, for example, learning about appropriate teaching strategies, other outcomes, such as STEM content knowledge did not appear to be developed to the same extent. However, this finding needs to be considered within the broader context of teacher learning, which as both Kennedy (2011) and Yurkofsky *et al.* (2019) argue, should be relevant and contextualised. In the case of the teachers who took part in this OLS, given their prior focus on and experience in STEM as part of their previous SE partnership activities, it was likely that they already held a relatively high degree of STEM content knowledge. Therefore, within the OLS, the learning they gleaned was appropriate and relevant for them within the context of their professional practice and in line with the needs of their students (Kennedy, 2011). Whilst it was not appropriate to do so in the context of the present study, which took a qualitative approach, future research could quantitatively examine teachers' STEM content knowledge pre- and post-engagement in OLS.

In the OLS described in this study, all teachers engaged in teaching of the research lesson and subsequently engaged in observation of their own practice by reviewing the video of their own lesson. The author had noted in their reflective diary their concern that not having the opportunity to observe another colleague teach and observe students interact with the research lesson activities would deprive teachers of potential learning opportunities.

If the teachers are not physically present in a classroom together for the research lesson, seeing one another teach and observing how the children engage in the activities, can I really be going around calling what we're doing Lesson Study? Or have I watered the whole thing down entirely?

(Author reflective diary entry, prior to post-lesson reflection meetings)

However, what emerged during reflection meetings was that this did not appear to be the case, with teachers' observation of their own research lessons providing significant insights and learning moments for both themselves as well as the other teachers in the team. During reflection meetings, teachers relied on their completed LS observation schedules, using these as stimuli to recount their individual experiences of teaching the research lesson. They collectively discussed how students had interacted with the planned learning activities during the research lesson, and used these discussions to derive shared insights for their future practice. Whilst the opportunity to see another colleague teach is an aspect of face-to-face LS which was absent during this OLS, instead, teachers had the opportunity to review their own practice using a collaboratively planned observation schedule. They then discussed their observations and reflected in focused detail with those in their OLS team, who had conducted the same research lesson with different students, in a different school context. In this way, from a theoretical perspective, OLS could be considered tightly aligned with Yurkofsky *et al.*'s (2019) online PD principles as earlier listed. Furthermore, in contrast with traditional face-to-face LS, where only one teacher teaches whilst the others observe, OLS provided an opportunity for *all* teachers to teach, review and reflect on their lesson. This was followed by an opportunity to share learning with colleagues who offered a variety of perspectives and insights, enabling boundary crossing. Thus the OLS provided a springboard for teacher dialogue, resulting in highly relevant practice insights for the teachers.

During the OLS, the teachers explicitly recognised the importance of engaging in adaptive practice, by planning a research lesson with flexibility built-in, which provided scope to meet the needs of students in their individual classes.

Findings indicated that the use of Zoom and Google Drive within OLS supported the sharing of different perspectives and ideas within the group of teacher learners (Mercer *et al.*,

2019) leading to the collaborative generation of knowledge (Hakkarainen, 2009) which was tightly aligned with practice. Learning how to use these digital collaborative tools represented a development in teachers' STEM content knowledge. Whilst this new knowledge was not operationalised by teachers in terms of pedagogy during this OLS cycle, engaging in further OLS cycles may have supported the teachers to explore how they might put this knowledge into practice with their students. The OLS supported the co-construction of artefacts such as lesson plans and teaching resources which were saved, revisited and modified (Pifarre, 2019). This would suggest that the dialogue which took place during OLS did not occur through explicit verbal interactions only, but was also implicit, with the process of exchange of ideas facilitated by digital boundary objects: OLS, Zoom and Google Drive. Given the small-scale nature and narrow scope of the STEMunities project, the author recommends that future research be undertaken on the affordances and constraints of digital boundary objects.

In terms of the sustainability of OLS as an adaptation to the traditional face-to-face LS model, the findings suggest that OLS provided a novel approach which allowed teachers in different schools to collaborate on LS in an efficient way which facilitated co-construction of knowledge. However, the pre-existing partnership which the schools were part of represented a supportive foundational structure which helped to facilitate the success of the OLS in this instance. Whilst beyond the scope of the STEMunities study, future research could focus on whether OLS could operate sustainably over multiple cycles and also explore the subsequent impact on outcomes for student learning.

Limitations

The study described in this paper was limited by its focus on OLS within the unique setting of an inter-school partnership in the Irish primary STEM education context, under extraordinary pandemic conditions. The qualitative discussion within this paper focused solely on the learning outcomes pertaining to STEM knowledge about teaching derived by participants engaging in one OLS cycle. Future research could focus on the processes by which these outcomes were derived and whether similar outcomes may be derived in other settings and contexts in non-pandemic times.

The STEMunities project was also limited by the multiple roles played by the author who served as OLS facilitator, KO and researcher. Whilst this insider positionality provided an opportunity for the author to share rich insights (Chavez, 2008), this also presented a limitation to the study. Given the novelty of the OLS approach and that this study represents the first time such an approach has been conducted in the Irish context, this ran the risk of both the participants and the researcher being more enthusiastic than they would be with a more established approach. Additional caution is required in such instances, in order to ensure rigorous critical analysis is conducted. In the case of the present study, and in line with Van Heugten's (2004) suggestion, mitigation of researcher bias was approached through the use of a reflective diary. Future research in the area of OLS could incorporate alternative methods of empirical inquiry, for example, by scholars not directly involved in the work of the OLS groups.

Conclusion

In conclusion, this study has contributed to the growing literature on OLS by providing empirical evidence that OLS offers promise as a vehicle to foster teacher collaborative learning in the context of primary STEM. Within the OLS conducted as part of this study, teachers' collaborative learning outcomes were facilitated using an OLS booklet along with Zoom and Google Drive tools. Together, these tools operated as boundary objects which

enabled boundary crossing opportunities for teachers at interpersonal and intrapersonal levels. For the teachers who took part, the OLS particularly supported learning outcomes which related to the STEMKT domain of learning about teaching. It is intended that this study will serve as springboard for further OLS research in other contexts and contribute to understanding on the how the various affordances of LS can be effectively translated into the online environment.

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Post OLS Interview Schedule Extract

Section 3: Perceptions of lesson study

193

1. In relation to our recently completed online Lesson Study, could you please describe, in as much detail as possible, any influences (positive or negative) that engaging in the project has had on
 - a. your day-to-day classroom teaching
 1. In general
 2. In STEM?
 - b. your interactions with colleagues
 1. In your own school
 2. In the other schools in your Shared Ed partnership schools?
 - c. Your professional knowledge?
 2. How would you sum up your experience of OLS?
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About the author

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