Exploring the prevalence of structured problem solving in research lessons: A post-intervention study from Ireland

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The purpose of this research was to investigate the incorporation of Structured Problem Solving in a Lesson Study initiative in Ireland. Since 2014, an annual average of 150 post primary mathematics teachers across 83 schools have participated in Lesson Study as a form of professional development. This has resulted in a published bank of research lesson plans, 145 of which were included in this research and analysed based on a framework of Structured Problem Solving. The results revealed strengths (e.g. students presenting their solutions) and weaknesses (e.g. teachers summarising lesson content) in the research lesson plans. The findings provide key insights for professional development regarding the incorporation of Structured Problem Solving in mathematics lessons and include recommendations for further research in this field.

Keywords: Lesson study, structured problem solving, teacher collaboration, professional development.

Introduction

In the context of educational reform, it is important that teachers are supported in continuously reflecting on and developing their pedagogical practice. Lesson Study, a collaborative approach to teacher professional development, has been demonstrated to have the potential to build teachers' content knowledge, pedagogical content knowledge, and improve learners' mathematical outcomes (Lewis & Perry, 2017; Ni Shuilleabhain, 2016). Research has also demonstrated that Lesson Study can support curriculum reform and contribute to changes in mathematics teachers' pedagogical practices (Ni Shuilleabhain & Seery, 2018). Mathematics curriculum reform worldwide has emphasised an increased focus on problem solving and Lesson Study has been identified as a way to encourage the enactment of specific problem-solving approaches, namely Structured Problem Solving (SPS) (Fujii, 2018; Nakamura, 2019).

In this research we examined artefacts created through Lesson Study, conducted with post-primary mathematics teachers across schools in Ireland. We based our analysis on the framework of SPS (Hino, 2007; 2015), which was a core focus of the introduction and implementation of this Lesson Study initiative since it aligned with the most recent national mathematics curriculum reforms. The research question addressed in this paper is as follows:

> How were the core features of SPS explicitly incorporated in research lesson plans created through teachers' participation in Lesson Study?

Lesson Study in Ireland

In Ireland, teacher education - through the continuum from initial teacher education, teacher induction, and continuing professional development - is overseen by the Department of Education through support services and other programme providers. The Professional Development Service for

Teachers (PDST), under the Department of Education, is the country's largest support service offering professional learning to teachers through its team of facilitators, who are seconded from teaching in their schools. Education policy advocates teacher collaboration as being a vital component of education reform and school improvement (Moynihan & O'Donovan, 2022) and since 2012 the PDST have incorporated Lesson Study in their approaches to professional development for mathematics teachers at post-primary level. This opportunity consisted of an introductory workshop to Lesson Study, resources to assist teachers in conducting a cycle of Lesson Study, and access to a PDST advisor for support in content and/or facilitation. From 2014, participating teachers were introduced to the concept of SPS (outlined below) and were encouraged to plan their research lessons incorporating this pedagogical approach. An average of 150 mathematics teachers across 83 schools have participated in Lesson Study each year since 2014 (Ni Shuilleabhain, 2019) (no figures are available on how many of these teachers participated over successive years) and research lesson plans created through Lesson Study cycles are available to review and download from the PDST website (PDST, 2023).

Beyond the PDST, teachers in Ireland have participated in Lesson Study through research endeavours across primary and post-primary levels at both in-service and pre-service education (e.g. Hourigan & Leavy (2022); Leavy & Hourigan (2016); Ni Shuilleabhain & Bjuland (2019)).

Structured Problem Solving

Following significant curriculum reform in Mathematics over decades in Ireland, problem solving has become a core focus of the post-primary mathematics curriculum. Conventional mathematics lessons, where the teacher demonstrates a process or procedure for students to practice, have been discouraged as they do not adequately prepare students to use mathematics in their lives or in future study (Sullivan et al., 2015). Rather than a sequence of skills to be learned in isolation, the recent reforms view mathematics as "an interconnected body of ideas and reasoning process that students negotiate collaboratively with their teachers and their peers and as independent learners" (NCCA, 2017, p. 4). Learners should therefore experience mathematics in a way which allows them to develop their understanding through different contexts, while also building their confidence and willingness to come up with solutions to problems they have previously not been shown how to solve.

Stigler and Hiebert (1999) described the outline of mathematics lessons in Japan as *Structured Problem Solving* and activities within such lessons are outlined to include the following (with numbers modified to mirror the coding utilised in this analysis):

1. Reviewing the previous lesson and presenting a preliminary problem for the day
2. Working on the problem individually and presenting the ideas
3. Presenting the problem for the day
4. a. Working on the problem individually
   b. Presenting solutions
5. Comparing the solutions, thinking of a convenient method, and summarising
6. Children's writing of comments on their learning

Comparison of multiple solutions, either from individuals or groups, is one of the critical parts of SPS (Fujii, 2018; Hino, 2015). A key task of the teacher in this activity is organising the classroom

discussion so that it culminates in highlighting the major point of the lesson, consolidates and extends students' understanding of content, and allows students to look back on their own way of attempting to solve the problem in a manner that is productive for their learning. Facilitating the discussion and comparing solution methods is often a challenge for teachers (Stein et al., 2008). Without careful consideration of which student approaches to discuss, in which order, and how they might be connected to contribute to the mathematical goal of the lesson, the discussion risks becoming "show and tell" with limited mathematical learning taking place (Stein et al., 2008). This necessitates advanced planning, where teachers should anticipate the possible approaches their students may take and consider how they will respond to and incorporate such approaches into the discussion. When engaged in productive discussions around a problem, learners can develop key mathematical skills in interpreting others' work, develop a sense of agency and identity in their learning, and can be empowered to try new and unfamiliar problem-solving techniques (Hino, 2015). Teaching through SPS habituates students to engage with unfamiliar and challenging problems and increases their inclination to persevere (Takahashi, 2021). Research has demonstrated that these classroom opportunities have capacity to bring deeper understanding to learners of the topic at hand (Davis & Simmt, 2003; Hino, 2015). This may require, however, a change in teachers' beliefs about students' capacity to problem-solve and beliefs around the role of the teacher in the classroom (Hourigan & Leavy, 2022; Wilson & Cooney, 2003).

Incorporating SPS could be considered a significant change from typical post-primary mathematics classrooms in Ireland. At post-primary level, mathematics lessons in Ireland have traditionally been heavily focused on procedures, teacher-led, and lacking in meaningful problem solving (Prendergast & O'Donoghue, 2014). Despite initial reforms intended to address this and incorporate more problem-solving practices into the classroom, more recent research suggests that little has changed (Prendergast & Treacy, 2018). Such findings suggest that professional development efforts have not supported teachers in making changes to their practice.

Methods

The purpose of this study was to explore the extent to which research lessons planned during teachers' participation in Lesson Study with the PDST incorporated SPS. All research lessons that had an associated PDF file available on the website were analysed.

In considering the methodology of this research, we regard instructional planning as an important process in teaching and particularly when implementing complex instructional strategies. We therefore utilised the lesson plans as qualitative material (Fernández, 2010; Ruys et al., 2012). Research from Meyen and Greer (2009) has previously demonstrated links between lesson planning and instructional behaviour and, in this research, we focused on the research lesson plans as a source of teachers' didactical and content objectives (as utilised by Tillema, 2009).

Based on the framework outlined by Hino (2007), 145 research lesson plans were analysed utilising NVivo software. Each lesson was analysed and coded for the inclusion of each element of the framework, with sub-codes detailed for certain codes. Coding of lesson plans was initially undertaken by one author, with another author taking a subset of these plans to code independently. The coding was compared to ensure alignment and was continued for all research lesson plans with the agreed-

upon codes. As a sample of coding, the following lesson excerpt (Lesson 106) in Figure 1 is an example of feature 3 '*presenting the problem for the day*'.

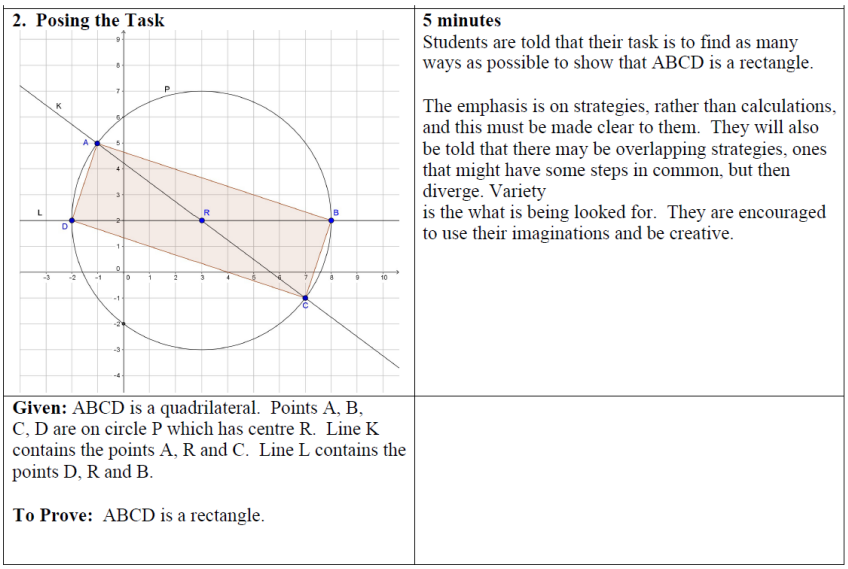

Figure 1: Lesson plan excerpt (no. 106) – presenting the problem for the day

An average of three teachers participated in the design of a research lesson, with 11 groups having only two teachers and one research plan designed by one teacher.

Findings and Discussion

In our discussion of these findings we focus on steps 3 to 6 of the approach as core elements of a lesson (Fujii, 2018). Figure 2 outlines the prevalence of these features of SPS in the analysed research lessons. A significant finding is that only 78 of the 145 research lesson plans (54%) incorporated a presentation of a problem for the day, with 67 lessons (46%) instead presenting learners with a familiar task or a series of stepwise tasks to work on.

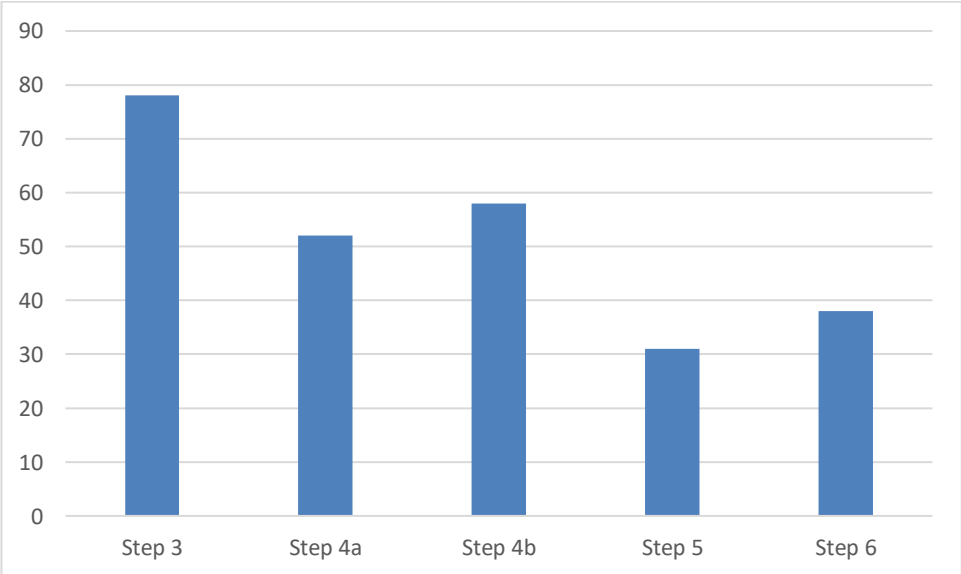

Figure 2. Prevalence of features of SPS according to number of published research lessons

Of the lessons presenting a problem to work on, 52 (36%) specified students working individually (others in pairs or groups) and 58 (40%) specified students presenting their work. Contrary to the pedagogy outlined by SPS, 13 of the lessons which posed a problem outlined teachers presenting solutions. Though 56 lessons (39%) specified students reflecting on their learning at the end of the lesson, only 38 (26%) asked students to do this in a structured way. Some of these utilised reflection prompts such as "two stars and a wish" or "how would you explain this lesson to a friend" to aid students' reflections.

Hino (2015) highlights the importance of preparing for the discussion element of the lesson and of anticipating students' thinking in order to facilitate the concluding classroom conversation, which were absent from a sizeable proportion of research lesson plans. Only 67 of the 78 plans presenting a problem had incorporated explicit anticipation of students' responses to the problem and only 45 of these outlined an order of solutions that might be presented within the lesson. A main weakness which appears in these findings is the intention for teachers to summarise the lesson in a way which develops students' understanding and expands their thinking on the topic (n=31; 21%). In the main, the summary was comprised of what students did in the lesson (n=38; 26%).

It is important to reference that from analysing the lesson plans, there seems to be a misunderstanding on behalf of participating teachers between 'Lesson Study' as a model of professional development and 'Structured Problem Solving' as a pedagogical approach:

> It is a central component of the whole Lesson Study process that, when students are presenting solution at the board, they must communicate verbally with the teacher and the class. The Teacher must ensure this. (Lesson 144)

In considering the findings of this research we note that the data is limited and that no data is available on teachers' beliefs or practices before or after their participation in the intervention. There is, therefore, no possibility of triangulating such data with information from the research lesson plans, as done by Fernandez (2010). We also acknowledge that the research lesson plans may not explicitly incorporate all elements of the lesson that was intended by teachers. Given the scale and longevity of the intervention, however, we consider it important to investigate (within the limitations of the data available) the impact that participation in such an intervention may have had. We also wish to recognise the success of the roll-out of the intervention in encouraging and facilitating so many post-primary mathematics teachers to participate in Lesson Study and engage with the concept of SPS, particularly considering the potential impact of such similar interventions on primary school teachers' beliefs around pedagogy and problem solving (Hourigan & Leavy, 2022).

Analysing all 145 of the lessons, it may be positive to note that 99 of them (68%) explicitly referred to students presenting their solutions. This denotes a move away from the traditional, didactic approach to teaching mathematics outlined above and signals a shift in the dialogue of the lesson from one solely governed by the teacher to moving towards the students. Such a move is likely to improve the agency and mathematical identity of students, thereby providing an opportunity to deepen students' understanding (Davis & Simmt, 2003; Takahashi, 2021). It is likely also positive that 117 of the 145 lessons (81%) asked students to reflect on their learning, although only 79 of these (54%) provided a structure for students' reflections.

With only half of the analysed lessons utilising SPS, and only six of these incorporating all elements of SPS, the research indicates that the approach of simultaneously introducing SPS and Lesson Study through an introductory workshop with resources and periodic facilitator support may not have been successful. Further research is needed to gain an understanding of why particular features of SPS were neglected in the lesson plans and what support teachers might require to aid them in more fully incorporating SPS in their lessons. Wilson and Cooney (2003, p. 142) note that in many failed efforts to affect teacher change, what is missing is "a basic shift in beliefs about what constitutes an appropriate role for the teacher of mathematics". Research exploring teachers' beliefs around their role, particularly in facilitating problem solving, would provide valuable insight for the roll-out of future professional development initiatives. Research investigating the provision of lesson plans incorporating SPS may also be useful (Sullivan et al., 2015), particularly considering recent reforms at Junior Cycle and the problem-solving focus of classroom-based assessments.

Post-primary mathematics teachers who participated in this professional development were willing to voluntarily spend time collaborating with colleagues. They did so without any formal acknowledgement for this additional time or effort, due to a vacuum in the system recognising professional development. Considering this personal investment of time, and the investment of resources by the Department of Education in providing this intervention, it is necessary to consider why regular, in-depth evaluative research is not conducted on the implementation and outcomes of such initiatives with a view to adapting and revising elements for greater success.

Quality teaching is a core element in enabling learner outcomes (Moynihan & O'Donovan, 2022). Providing teachers with high-quality, supportive, professional development is key to this outcome. In their research on schools in Ireland, Moynihan & O'Donovan (2022) suggest that policy makers should identify and make explicit exemplars of effective collaborative models of teaching and learning, relevant to each school context and to an increasingly changing and challenging profession. Given the breadth and scope of this intervention by policy makers to introduce both Lesson Study and SPS, it would be beneficial to plan for and structure research on the impact of such initiatives, particularly where they have such rich potential to impact classroom practices and student achievement.

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