Supporting teachers to engage with Structured Problem Solving in their Junior Cycle classrooms –developing Educative Curriculum Materials for use with Lesson Study

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Successive curriculum reforms in Ireland have led to an increased emphasis on problem-solving approaches to teaching mathematics. However, there is little research to suggest that classroom practices have changed significantly. In this paper we outline the design of a set of Educative Curriculum Materials (ECMs) as part of a professional development intervention, which aims to support teachers to incorporate Structured Problem Solving into their classroom practice. These materials are designed to be used in Lesson Study as part of a professional development intervention. We begin by describing Structured Problem Solving and the challenge it poses for teachers, before outlining the role professional development, and specifically ECMs, can play in supporting teachers with this approach. Finally we highlight some key features of the ECMs currently being developed.

Keywords: Structured Problem Solving, Educative Curriculum Materials, professional development, curriculum reform

Introduction

Over the past 15 years curriculum reforms in Ireland have encouraged teachers to adopt a problem-solving approach to teaching mathematics in post-primary classrooms. However, there is little evidence that classroom practices have changed as envisaged by the reforms (Byrne & Prendergast, 2020; Jeffes et al., 2013). Recent research has highlighted the high levels of concern teachers hold about these reforms and their discomfort implementing problem-solving approaches (Berry et al., 2021; Byrne & Prendergast, 2020; Neururer & Ni Shuilleabhain, 2022). Teachers are unsure how to incorporate problem-solving into their classrooms and lack well-designed resources to support them with this in their planning and teaching (Neururer & Ni Shuilleabhain, 2022). Several studies have examined how professional development interventions can support teachers to incorporate problem-solving approaches in their classrooms (Hourigan & Leavy, 2022; Sullivan et al., 2015). However, teachers' beliefs about what constitutes effective teaching and about their role in the classroom can impact their intention to implement changes to their classroom practice (Maass, 2011). Those initiating curriculum reform often fail to consider the teacher's seminal role (Spillane 1999) and this failure at a structural, systems level may be contributing to the poor enactment of problem-solving practices in post-primary classrooms.

This paper outlines the design of Educative Curriculum Materials (ECMs) as part of a professional development intervention incorporating Lesson Study, which aims to support teachers to incorporate problem-solving into their daily practice. Building on the work of Fujii (2018), teachers will be invited to discuss, plan, conduct and reflect on SPS in the classroom within Lesson Study. The supporting material within the ECMs focus on the key role of the

Neururer, R. & Ni Shuilleabhain, A. (2023). 'Supporting teachers to engage with Structured Problem Solving in their Junior Cycle classrooms – developing Educative Curriculum Materials for use with Lesson Study'. Presented at MEI 9, 10-14th October 2023, DCU.

teacher in orchestrating discussions within SPS (further detailed below) and utilises the five practices highlighted by Stein et al. (2008) as a way to promote approaches to problem-solving. For the purposes of this study the materials align with the teaching of algebra at 2nd year (13/14years), one topic where students' poor performance has been identified (Prendergast & Treacy, 2018).

Structured Problem Solving

The emphasis on problem-solving in successive curriculum reforms at post-primary level, first in 2000 and later in 2017, marks a significant departure from conventional mathematics lessons to a new way of considering teaching and learning in the mathematics classroom (Ni Shuilleabhain & Seery, 2018). In the former approach the teacher demonstrated procedures for students to practice and there was little emphasis on mathematical reasoning and discussion (Prendergast & O'Donoghue, 2014). By contrast, 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). This approach requires an adjustment in the role of the teacher away from transmitting knowledge and demonstrating procedures, towards one of facilitating mathematical discussions and supporting students to engage with challenging mathematical tasks (Takahashi, 2021).

Stigler and Hiebert (1999) describe the outline of a problem-solving approach to teaching mathematics in Japan as *Structured Problem Solving*. This pedagogical approach involves students learning new mathematical ideas, while grappling with carefully chosen mathematical problems. This contrasts with the "one-off", strategy-focused teaching of problem-solving which often occurs outside of the curriculum content (Takahashi, 2021). Structured Problem Solving (SPS) broadly involves a four-phase lesson structure whereby a problem is posed, students work to explore the problem, different approaches and solution methods are discussed and, finally, the teacher summarises the lesson (Fujii, 2018). Hino (2015) adds an additional stage of "reviewing the previous lesson" in his outline of SPS in Japanese classrooms, while others (Stein et al., 2008; Sullivan et al., 2015) consider a 3-phase lesson structure in which the discussion and teacher summary are consolidated into a single phase. However, regardless of the lesson structure, students engaging with a problem with and a carefully orchestrated whole class discussion about potential approaches to that problem are key elements of a SPS lesson. Indeed, the whole-class discussion has been described as the "heart" of the lesson (Takahashi, 2021).

Teaching through SPS is challenging. Teachers need to organise and manage the classroom discussion in a way that moves the learning forward. Stein et al. (2008) argue that without careful planning, including consideration and anticipation of which particular students' methods will be appropriate to discuss, in what order methods might be presented , and how disparate ideas and approaches might be connected to contribute to the mathematical goals of the lesson, the classroom discussion risks becoming "show and tell" with limited mathematical learning occurring. While in Japan the textbooks (which are approved by the

Ministry of Education) support teachers in this approach (Watanabe, 2019), there are few resources or textbooks available to support teachers with SPS in other education systems (Takahashi, 2021). For many students and teachers, SPS is an unfamiliar pedagogy which necessitates a significant shift in their role in the classroom.

Rather than dispensing knowledge, demonstrating procedures, and sanctioning correct approaches, SPS requires teachers to facilitate students' engagement in problem-solving by orchestrating learning environments in which students can grapple with challenging problems and participate in productive mathematical discussions (Stein et al., 2008). This shift in role is challenging for teachers and, without expectations for what might happen or guidance on what a teacher could do, many teachers are left feeling they should avoid telling students anything, leading to a reduction in their self-efficacy (Stein et al., 2008).

Professional Development for SPS

Research suggests that effective professional development is grounded in teachers' practice, engages teachers as active learners, is collaborative and is ongoing (Darling-Hammond et al., 2017). Many studies have demonstrated that Lesson Study is an effective way to enable teachers to re-consider their role in the classroom and attempt new pedagogical practices (Lewis & Perry, 2017; Ni Shuilleabhain & Seery, 2018). However, recent research analysing lesson plans from post-primary teachers engaged in Lesson Study with an aim of incorporating SPS found the initiative not wholly successful (Ni Shuilleabhain et al., in press). Fujii (2018) describes Lesson Study and SPS as "two wheels of the same cart" in the Japanese context, where this model of professional development supports teachers in incorporating SPS in their practice. The cultural contexts of educational initiatives are important to acknowledge however (Stigler & Hibert, 2016) and there is therefore a need to consider other forms of structured professional development interventions which will allow teachers the opportunity to consider the required classroom reforms of SPS.

Educative Curriculum Materials in Professional Development

All teachers use curriculum materials of some form in their planning and teaching of lessons. Consequently, curriculum materials are well placed to influence and support teachers' practice. For those with a focus on teacher learning, a challenge arises in ensuring such materials are used effectively. This challenge is even greater when the materials in question aim to instigate change (Stein & Kim, 2009). However, curriculum materials have the potential to contribute to professional practice and teacher learning if they are designed with this purpose in mind (Ball & Cohen, 1996; Davis & Krajcik, 2005). Such curriculum materials which aim to support teacher learning as well as student learning are called Educative Curriculum Materials (ECMs) (Davis & Krajcik, 2005).

A key feature of ECMs is their transparency. Rather than merely providing instructions and strategies for teachers, they also provide the rationale for the various implicit pedagogical decisions (Davis & Krajcik, 2005). By making the pedagogical rationale for different suggested strategies explicit, ECMs help teachers make good decisions about adapting curriculum resources. By utilising ECMs in curriculum reform, teachers can be

supported in changing their practices with reasoning and understanding, making adaptations to their practice within the spirit of the reform.

Although ECMs have the potential to contribute to teachers professional learning, there is agreement that they are best used alongside other forms of professional development (Davis & Krajcik, 2005; Fuentes & Ma, 2018). Indeed, Fuentes & Ma (2018) highlight the need to investigate how teachers' use of, and learning from, ECMs can be enriched through other supports. Our research aims to investigate how engaging in Lesson Study can support the use of ECMs as a form of professional learning.

Design of Educative Curriculum Materials

The ECMs in this research have been designed to support teachers to engage with SPS in their classrooms. As discussed above facilitating mathematical discussions is a central component of SPS, however it is challenging for teachers and may demand a change in their role in the classroom. Thus, the materials aim to help teachers with the shift in role required of them, by incorporating specific guidance on how they might orchestrate these whole-class mathematical discussions. In particular, the five practices outlined by Stein et al. (2008) are employed. These five practices consist of *anticipating* students' mathematical responses to the task, *monitoring* students' approaches, purposefully *selecting* specific student responses for presentation, purposefully *sequencing* the order of student presentations, and *connecting* the student responses in a meaningful way. Each of these practices draws on, and benefits from, what was learned from the previous one. In the ECMs designed for this research, these five practices are highlighted throughout the materials with concrete examples provided and "callout boxes" encouraging teachers to engage and reflect on their use of these practices (see Figure 1). By reviewing the materials and tasks within them, teachers can develop a deeper understanding of the pedagogical practices required for SPS. They can choose to use the tasks in their research lessons or consider others, using the ECMs to support them with incorporating the five practices and with orchestrating productive discussions as part of SPS in their classrooms.

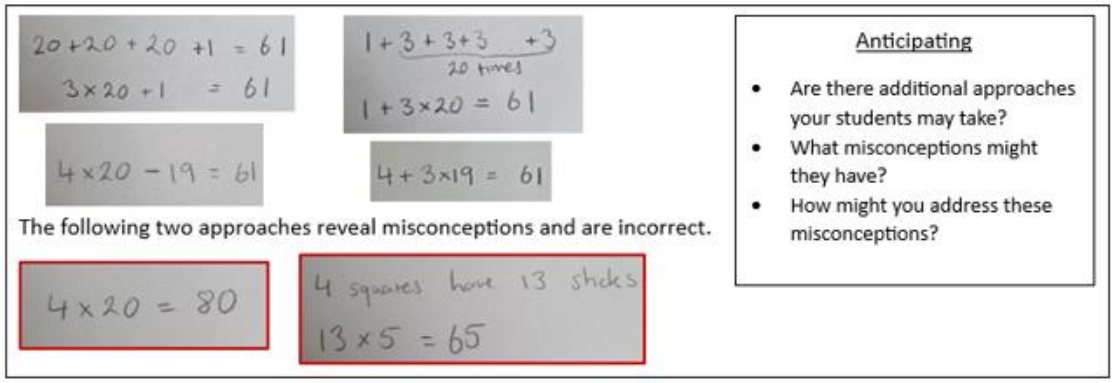
In designing ECMs, it is important to note that teachers frequently adapt and modify resources to suit their classroom contexts and learning goals (Calleja et al., 2023). Specifically in the context of SPS, Calleja et al. (2023) highlight how teachers often introduce scaffolds for their students in problem-solving and may deviate from the 4-phase lesson structure of SPS in their classrooms. While scaffolding students' learning can be an important element of building students' skills, it is important that such scaffolds offered by the teacher do not undermine the problem-solving element for learners (Foster, 2019). Rather than simplifying the task, or narrowly helping students to solve the problem at hand, teacher guidance should therefore aim to focus students' attention on key features of the task to enable them to engage productively with it (Calleja et al., 2023). In this context, the use of enablers and extenders can help teachers adjust the level of support provided to students without eliminating the problem-solving aspect of the task (Charalambous et al., 2022; Sullivan et al., 2015). The ECMs designed for this research will suggest possible enabler and extender approaches for

teachers to engage with. For example, an enabler might make a particular heuristic clear to a student or identify key features of the task so that a student struggling to start can be supported to make an attempt at the problem. Throughout the materials we endeavour to highlight and identify key features of possible scaffolded adaptations, so that teachers are supported in making informed decisions about how to incorporate, and possibly adapt, SPS in their classrooms in a way that the key features of SPS are not diminished (Calleja et al., 2023).

Building on the work of Davis and Krajcik (2005), and using the framework of Fuentes and Ma (2018), the materials are designed ensuring pedagogical decisions are transparent and with reasoning given for the inclusion of different elements. As outlined above, a key aspect of SPS is the discussion of student approaches in such a way that moves student learning forward. The materials therefore aim to support teachers with orchestrating such productive mathematical discussions, by incorporating specific guidance focused on the five practices of Stein et al (2008).

Figure 1

Sample of the features of the purposefully designed ECMs: Callout box drawing attention to the practice of anticipating; examples of possible student approaches and misconceptions.



Future Phase of the Research

A range of ECMs will be designed and shared with teachers in two case study schools, who will trial them through school-based Lesson Study with their colleagues. Potential extenders and enablers will be included for various problems identifying how various tasks can be adjusted according to the students' prior knowledge and experience with problem-solving. By aiding teachers to anticipate students' responses in their collective planning in Lesson Study, it is hoped that the ECMs will prepare teachers to effectively facilitate whole-class discussions and, consequently, help them incorporate SPS into their classrooms (Fujii, 2018). It is also hoped that they will support teachers adopt the change in role demanded of

them in incorporating problem-solving approaches in their practice, by providing concrete guidance for their in-the-moment decisions and pedagogical ideas.

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