An analysis of Irish mathematics textbook tasks in the context of curriculum change

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This study is concerned with the analysis of mathematical textbook tasks at second-level in Ireland, in the context of the introduction of the revised curriculum entitled ‘Project Maths’. A total of 7635 tasks on the topics of Pattern, Sequences and Series, and Differential Calculus were analysed; these tasks were selected from editions of three textbook series available before and after the curriculum change. The analysis was carried out using a framework specially formulated for the purposes of this study, based on an amended version of the Project Maths objectives centred on its representation/characterisation of ‘synthesis and problem-solving skills’. Our findings suggest that the post-Project Maths textbook tasks offer more problem-solving opportunities compared to those in the older textbooks, but that there is still much scope for further development. Based on our analysis, it would appear that all three textbook series have neglected important objectives of the Project Maths curriculum such as providing opportunities for students to devise models/techniques and translate information from written to mathematical form.

Keywords: intended curriculum; problem-solving; mathematical tasks; textbook analysis

Introduction

A major revision of the second level mathematics curriculum has taken place in Ireland over the last decade and a half. The new curriculum (entitled *Project Maths (PM)*) was developed after a wide consultation with the mathematics and education communities (National Council for Curriculum Assessment (NCCA), 2006). A major focus of the new mathematics syllabus is problem-solving which it defines as “engaging in a task for which the solution is not immediately obvious” (NCCA, 2012, p. 10). In this paper, we will view the curriculum change through the lens of textbook tasks. Curriculum change is often a challenging process for educators as well as students (Lubienski, 2011) and it can be difficult for researchers to gain insight into the progress of the reform. One way to investigate this topic is to consider the resources used by teachers (Remillard & Heck, 2014). Many researchers have argued that what students learn and how they think about mathematics is shaped by the tasks with which they engage (Henningsen & Stein, 1997; Polya, 1957) and so the aim of our study was to gain greater insight into the nature of tasks that students and teachers work with in Irish classrooms (before and after the curriculum reform).

Despite there being a large number of digital resources available to schools, it has been reported that even with some limited successes, "there is still much room for improvement in embedding digital technologies in teaching, learning and assessment in Ireland" (Feerick, Clerkin & Cosgrove, 2022, p. 32). The situation with Mathematics teachers appears to be no different as they rely heavily on textbooks to structure their classes and as the main resource for classroom and homework tasks (Duffy & Brennan, 2022; Shiel & Kelleher, 2017, Dunphy, 2009; Harbison, 2009). However, Ireland has no system for the approval of textbooks nor are any specific instructional materials officially prescribed for the teaching of mathematics (Mullis, Martin, Foy & Arora, 2012) – rather textbook production is a purely commercial undertaking. As a result, Irish textbooks may reflect an author's individual preferences. In such a system, it is particularly important to evaluate the textbooks available against curricular specifications and to examine how they mediate the stated objectives of the curriculum. Specifically, the study of the features of tasks provided in textbooks before and after the Project Maths (PM) curriculum reform can give us information on how this reform was implemented in Ireland.

This paper reports on the analysis of over 7000 mathematical textbook tasks from the most popular second-level mathematics textbooks in Ireland at that time. The tasks analysed were those given in the exercise sections of the textbooks and included both routine questions and non-routine problems. In the analysis of tasks, attention was paid to the mathematical content of the tasks and the skills that students are assumed to utilise in their interaction with the task when attempting to provide a solution.

Background to the study

The importance of textbooks

It has been found that "mathematics textbooks have significant influence on students' opportunities to learn mathematics in many classrooms" (Stylianides, 2009, p.259), and there is a danger that students' learning can be limited by a deficient textbook (Sievert, Van Den Ham & Heinze 2021; Hadar, 2017). A well-designed textbook provides guidance in the teaching process (Fan, Cheng, Xie, Luo, Wang & Sun, 2021; Van Steenbrugge, Larsson, Insulander & Ryve, 2018; Haggarty & Pepin, 2002), by organising teaching and learning and supporting the development of thinking and understanding within a subject (Fan, Zhu & Miao, 2013; Hadar & Ruby, 2019). Teachers using different types of textbooks make use of different styles of teaching strategies (Fan & Kaeley, 2000; Stein, Remillard & Smith, 2007; Sievert et al., 2021) and different textbooks can result in different student learning outcomes (Sievert et al., 2021b; Haggarty & Pepin, 2002; Xin, 2007).

Indeed, Houang and Schmidt (2008) view textbooks as the potential implemented curriculum, with the choice of content included providing some opportunities to learn at the expense of others. But it is important to be aware that textbook analysis examines only the *potential* implemented curriculum; teachers can use textbooks in several different ways influenced by their individual preferences and circumstances (Charalambous, Delaney, Hsu & Mesa, 2010; Remillard, 2005; Thompson & Senk, 2014) and build on and extend what is presented in the textbook.

However, the analysis of mathematical textbooks has a role in gaining insight into the implemented rather than intended curriculum (Valverde, Bianchi, Wolfe, Schmidt & Houang, 2002; Fan et al., 2013; Johansson, 2003; Houang and Schmidt, 2008; Usiskin 2013; Rezat, Fan & Pepin, 2021) and has been used to study curriculum initiatives internationally in countries like Norway, Croatia, and the US (Bakken & Andersson-Bakken, 2021; Glasnovic Gracin, 2018; Ma, Bofferding & Xin, 2021). In Irish mathematics classrooms, research has found that teachers largely base instruction on commercially published textbooks, supplemented by past examination papers (Mullis et al., 2012). Very often the textbook is the only resource which students have access to during the lesson aside from the teacher, while most of the tasks assigned for mathematics classwork and homework (in Ireland) come directly from the textbook (Professional Development Service for Teachers (PDST), 2020).

The importance of tasks

For those attempting to understand mathematics teaching and learning by researching classroom practices, mathematical tasks are an important aspect of study (Shimizu, Kaur, Huang & Clarke, 2010). Here we follow Stein, Grover and Henningsen (1996, p. 460) in regarding a mathematical task as an "activity, the purpose of which is to focus students' attention on a particular mathematical idea", though we include activity students engage in as homework as well as that in the classroom, and we will use 'task' to refer to a single mathematical question, problem or exercise. Tasks present learning opportunities to pupils through the activities in which they invite pupils to participate. Polya (1957) and Henningsen and Stein (1997) both acknowledge that students' sense of mathematics develops from their experiences with the tasks with which they are asked to engage. This can either limit or broaden their views of the subject. Furthermore, Sullivan, Clarke and Clarke (2012) contend that mathematical thinking stems from students’ engagement with problem-like tasks as opposed to following a series of detailed instructions from the teacher.

Studies of mathematics textbook tasks have been used to investigate how texts align with the curriculum for which they were designed in many countries including Sweden (Johansson, 2003), the USA (Herbel-Eisenmann, 2007) and Croatia (Glasnovic Gracin, 2018). Bayazit (2013) showed that textbooks produced in Turkey in response to major curriculum change did conform to the expectations of the curriculum writers. However, many studies show that textbook series and their set of tasks do not always adequately represent the intended curriculum and can often underrepresent, neglect or even omit key material (Johansson, 2003). For this reason, we posit that using curriculum objectives to develop a framework with which to classify textbook tasks is a way of investigating how textbooks mediate the implemented curriculum.

Irish Educational Context

In Ireland, secondary education consists of two parts – a junior cycle and a senior cycle. The senior cycle involves two years of study and the subjects studied are assessed by means of a terminal state examination, called the Leaving Certificate (LC). This is a high-stakes examination as entrance to university is entirely determined by LC results. At senior cycle, subjects are normally studied at either Ordinary or Higher Level, although mathematics can also be studied at Foundation Level (Department of Education and Science (DES)/NCCA, 1992). The Higher Level course is aimed at the more able students with a special interest in the subject; the Ordinary Level course provides knowledge and techniques that will be necessary for the study of scientific, economic, business and technical subjects at third level; while the Foundation Level course provides students with the mathematical tools needed in their daily life and work (DES/NCCA, 1992). While mathematics is not compulsory in the senior cycle, the proportion of students retaining mathematics as a subject remains high: in 2019, 98% sat the examinations in mathematics. The majority of these candidates, 57%, sat the Ordinary Level examinations, 33% sat the Higher Level examinations while 10% took the Foundation Level (State Examinations Commission (SEC), 2019). For the Irish market, there are currently five textbook series catering for Higher and Ordinary Level respectively. For Foundation Level, there are two textbooks available which reflects the smaller cohort involved. Very often, students follow the Ordinary Level syllabus and change to Foundation Level in the months directly preceding the examinations. In this situation, students retain the Ordinary Level textbooks supplemented by past Foundation Level examination papers and worksheets pitched at this level.

In Ireland, the choice of textbook to follow for a particular subject is generally made by a group of subject teachers within a school or sometimes by an individual teacher. The production of textbooks is a commercial enterprise and while the DES and the NCCA keep the Irish Educational Publishers' Association (IEPA) informed regarding emerging curricular developments, neither the DES nor the NCCA commission or recommend textbooks for use in schools (IEPA, 2021).

Curriculum Reform in Ireland

The second level mathematics curriculum in Ireland remained largely unchanged for the 30 years prior to the PM reform initiative. The syllabus from that era (DES/NCCA, 1992) lists core topics in the areas of Algebra, Geometry, Probability and Statistics, and Calculus. In addition, the document lists fundamental *examinable* objectives of the course:

A. recall of basic facts;

B. demonstration of instrumental understanding;

C. acquisition of relational understanding;

D. application of knowledge and skills in familiar contexts;

E. development of psychomotor and communicative skills necessary for A-D.

It also outlines other objectives which would *not be examinable*:

- appreciation of mathematics,
- analysis of information including the formation of suitable models and selection of appropriate solution strategies;
- the creation of mathematics by students themselves by exploring patterns, formulating conjectures, and supporting and explaining findings.

Studies carried out in the early 2000's (Conway& Sloane, 2005; Lyons, Lynch, Close, Sheerin & Boland, 2003) as well as the Chief Examiner's Report (SEC, 2005) suggested that the teaching of mathematics in Ireland placed a heavy emphasis on the use of procedures and less on understanding the concepts underlying them. The Chief Examiner's Report also commented on a deficit "in the capacity of students to engage with problems that are not of a routine and well-rehearsed type" (SEC, 2005, p.72) and documented weaknesses in the performance of students stemming from "underdeveloped problem-solving and decision-making skills" (SEC, 2005, p.73).

In light of these findings the new PM syllabus was introduced by the NCCA between 2008 and 2015. The mathematical topics covered are similar to the old syllabus and are organized into five strands: Statistics and Probability, Number, Algebra, Geometry, and Functions. The objective of the syllabus is that "learners develop mathematical proficiency" (NCCA, 2012, p.6) which consists of the five interdependent and interwoven strands – namely, procedural fluency, conceptual understanding, strategic competence, adaptive reasoning and productive disposition - as characterized by Kilpatrick, Swafford and Findell (2002). The PM syllabus document also emphasizes students' problem solving-skills and an appreciation of connections within mathematics as well as between mathematics and real life (NCCA, 2012). Moreover, it outlines the importance of tasks:

> The quality of the tasks that learners engage with plays an important role in a problem-solving environment. A task must engage learners and present them with a challenge that requires exploration. Problem-solving tasks activate creative mathematical thinking processes as opposed to imitative thinking processes activated by routine tasks. (NCCA, 2012, p. 10)

Alongside the learning outcomes for each of the five strands of the PM syllabus is the following text:

> *As they engage with this strand and make connections across other strands, learners develop and reinforce their synthesis and problem-solving skills. At each syllabus level students should be able to*
>
> - *explore patterns and formulate conjectures*
> - *explain findings*
> - *justify conclusions*
> - *communicate mathematics verbally and in written form*
> - *apply their knowledge and skills to solve problems in familiar and unfamiliar contexts*
> - *analyse information presented verbally and translate it into mathematical form*
> - *devise, select and use appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions.* (NCCA, 2012, p. 15)

These are what we will call the Project Maths Objectives (PMO). Even though many of these objectives also appear in the old syllabus documents (e.g. exploring patterns, explaining findings), it was explicitly stated there that many of them would not be examinable. This was not the case with the new syllabus. Indeed, a support service tasked with assisting teachers with implementing the new curriculum over a transitional period emphasized these problem-solving objectives and synthesis skills when developing resources such as teacher handbooks and video presentations.

We used these objectives to create the PMO Framework, and analysed tasks from a range of textbooks (from before and after the curriculum reform) in relation to it. More details on the framework are given in the methodology section of this article. Given the prevalence of the textbook as a source of tasks in Irish mathematics classrooms, we chose to use these collections of tasks as a lens through which to view how the problem-solving and synthesis objectives of the PM curriculum are manifested.

Research on curriculum reform in Ireland

Other studies have considered other aspects of the implementation of the PM curriculum. O'Keeffe and O'Donoghue (2012) conducted a study of the textbooks published in response to PM that were available at the time (ten in all), using an adaptation of the TIMSS curriculum framework (Valverde et al., 2002). The study found that all textbooks analysed fell short of the standard needed to support the intended PM curriculum effectively, but that some of the new textbooks were better aligned to PM expectations than others. O'Keeffe and O'Donoghue (2012) called for a review of available textbooks and the production of a list of officially approved texts. This has not yet happened. While the O'Keeffe and O'Donoghue study focused on content, Davis (2013) examined the prevalence of reasoning-and-proving tasks in the topic of complex numbers in six Irish textbooks and one teaching and learning plan produced for teachers during the introduction of PM. The results from Davis' study suggest that the six textbook units do not align with the PM syllabus in this area, however little is known about progress on the other objectives outlined in the PM syllabus.

The impact of Project Maths on student achievement, learning and motivation was explored in research commissioned by the DES and NCCA and reported on in Jeffes, Jones, Wilson, Lamont, Straw, Wheater & Dawson (2012). This research did not involve textbook analysis but rather required students in 60 schools to complete surveys and assessments, followed by more in-depth case studies using student focus groups and teacher interviews in 16 schools. They found that, whilst some elements of the revised PM syllabuses were visible in some of the student material reviewed, there had not been a substantial shift in what teachers are asking students to do at that point (two years after the new syllabuses had been introduced in all schools). In particular, there was very little evidence of reasoning and proof, of communication of mathematical ideas, or of making connections between topics in student work, leading Jeffes et al. (2012) to recommend that students should regularly be given high quality tasks that require them to engage with these processes.

In light of this recommendation and of the scarcity of information on how well different textbook series align to the new syllabus, we will consider the following research questions in this paper:

- What proportion of the tasks in each of the textbooks address each of the Project Maths Objectives?
- How do these proportions differ between the textbooks produced before and those produced after the introduction of the curriculum reform?

These questions have not been comprehensively studied in the Irish context to date. Mathematics teachers, charged with implementing the reformed curriculum, are keen to find textbooks that support its objectives. This article will focus on reporting results found using the PM syllabus problem-solving objectives framework, which was developed specially for this project. Note that this work is part of a larger study where the analysis made use of four other task frameworks (O'Sullivan 2017).

Methodology

We classified a selection of tasks from textbooks published before and after the curriculum changes to investigate both how the new textbooks reflected the PM goals in relation to synthesis and problem-solving skills, and the extent of change in the potential implemented curriculum. For this undertaking, we decided to focus on the textbooks for senior cycle and chose the three textbook series that were the most popular at that time. In order to classify the tasks, we developed a framework using the description of problem-solving and synthesis skills used in the syllabus itself. We will describe this framework below.

The Project Maths problem-solving Objectives (PMO) framework

The list of synthesis and problem-solving skills to be developed and reinforced (NCCA, 2012) is reproduced in the left-hand column of Table 1. In order to formulate these objectives as a useful framework for the classification of tasks and to get a clear picture of whether textbook tasks are meeting these objectives, it was necessary to make some minor modifications to the objectives listed (see right-hand column of Table 1). Information presented by textbook tasks is generally encountered using the written form and so the original fourth objective shown in Table 1 was modified by removing the word "verbally" before using it for classification. A similar modification was made to the sixth (original) objective.

[Table 1 near here]

Table 1. Original/Amended list of Project Maths problem-solving syllabus Objectives

Objectives which covered multiple situations were also broken down. In particular, with reference to contexts, it was deemed useful to distinguish between familiar and unfamiliar settings as one of the goals of the revised curriculum was to introduce more unfamiliar contexts into the teaching and learning of mathematics. Therefore, the fifth objective was split into two objectives (5 and 6) in the amended list which would come to be our framework for the classification of tasks. Another important distinction had to be made between the very different actions of *devise*, *select* and *use* grouped together in the original final objective; this was achieved by including three separate objectives (8, 9 and 10) in our framework. We used the classification *Use* (Objective 10 in our framework) when students were asked to work on a task for which they had already seen a complete solution method. If students had access to a range of possible solution methods (from previous exposition) and needed to choose an appropriate method or technique, we classified that task using *Select* (Objective 9). Finally, if the task was entirely novel and students had to construct a new (to them) solution method we classified the task using *Devise* (Objective 8). We note that in order to make the distinction between Objectives 5 and 6, and between Objectives 8, 9, and 10 we needed to pay close attention to the expository material in the textbooks. This allowed us to decide if a context was familiar or not for the students, and crucially to distinguish between tasks which required students to use a previously-seen method, to choose between methods, or to devise their own method.

To distinguish between objectives 2 and 3 for the purposes of classification: *Explain Findings* was chosen if a task asked students to interpret their solutions, while tasks that required students to provide some proof or evidence were classified in the category *Justify Conclusions*. For objectives 5 and 6, a ‘problem’ is viewed as something that contains an element of non-routine material which requires some engagement on the part of the student in order to solve it and involving the use of skills in a new or different way. An illustration of how the framework was applied to sample tasks is included in the following section. We would like to note that it is possible for a task to meet multiple objectives but we have listed the primary objective only here.

Illustration of Classification of Tasks

Let's consider tasks on the subject of Rules of Differentiation. For the purpose of classification, it is useful to know what kind of expository material is available to students in their textbook. So let's assume that the book has: motivated the introduction to differentiation using slopes of tangent lines and rates of change; derived the formulae for the derivatives of $f(x) = x^n$ (where *n* is a natural number) and $g(x) = \sqrt{x}$ from first principles; derived the constant multiple rule, sum and difference rule, and product and quotient rules from first principles; found derivatives of basic functions using these formulae and rules. We will now classify a range of possible tasks on these topics, each of which illustrates a particular objective.

Example 1: Find the derivative of $f(x) = \sqrt{x}/(x^2 + x^3)$.

Classification: Objective 10

Reason: Students need to <u>use</u> the quotient rule, the sum rule, and the formulae for the derivatives of $\sqrt{x}$ and x^n . All of these are available in the expository material.

Example 2: Find a function $f(x)$ such that its derivative is $x^2 + 2x - 3$ and $f(0) = 1$.

Classification: Objective 8

Reason: Students need to come up with a technique to solve this task while drawing on their knowledge of the derivatives of polynomials. Based on the expository material, we can conclude that students would not have seen a problem like this before, and would not have experience of integration so they are being asked to devise this method.

Example 3: Use the definition of the derivative to show that the derivative of the constant function $f(x) = c$ is zero.

Classification: Objective 3

Reason: Students need to use the method of first principles to justify that the derivative of a constant function is zero.

Example 4: From your knowledge of graphs, explain why it makes sense that the derivative of a constant function is zero.

Classification: Objective 2

Reason: Students need to use their knowledge of graphs and of the connection between derivatives and slopes to explain the finding from Example 3.

Example 5: Use the product rule to find a formula for differentiating a product of three functions. That is: what is $(f(x)g(x)h(x))'$?

Classification: Objective 5

Reason: Students need to apply the product rule (which is familiar to them) to create their own rule for differentiating *f(x)g(x)h(x)*. Even though the product rule and the context is familiar, the task itself is novel and the solution would not be immediately obvious to students.

Example 6: Given what you know about the rules for differentiating *f(x)g(x)* and *f(x)g(x)h(x)*, can you predict what the rule for differentiating *f(x)g(x)h(x)k(x)* would be?

Classification: Objective 1

Reason: Students need to explore a pattern using the product rules for two and three functions and the make a conjecture as to what the rule for the product of four functions would look like.

Choice of topics

In selecting tasks for analysis, we restricted ourselves to the topics of Pattern, Sequences and Series, and Differential Calculus because they are present on both Higher and Ordinary Level Leaving Certificate Mathematics syllabuses and together form a substantial proportion of the course. In addition, both were also present on the syllabus before the PM curriculum review and so analysis of tasks on these topics allows for comparisons between the old and new textbooks. We also note that students often find these topics difficult; indeed a recent presentation by the state examiners highlighted particular difficulties with the topic of Pattern, Sequences and Series (especially arithmetic and geometric sequences), and with Differential Calculus (especially rates of change, graphing, and optimisation) (Irish Mathematics Teachers' Association (IMTA), 2021)

Choice of Textbooks

We analysed tasks from three textbooks series available on the Irish market: referred to as Text A, Text B and Text C. These three textbook series were selected because they were the first to be published in response to the new curriculum, while they have also traditionally been the most popular in Irish classrooms. This allows for comparison between the older textbooks and the textbooks introduced in response to PM.

Selecting tasks

From the six Pre-PM and six Post-PM textbooks (i.e. one at Ordinary Level and one at Higher Level for each of Text A, B and C), each chapter relating to the topics of Patterns, Sequences and Series and Differential Calculus was analysed. We analysed tasks from the exercise sections of these chapters; note that the worked examples given in the text of each chapter were treated as expository material. A total of 7635 tasks (3584 Pre-PM and 4051 Post-PM) were classified from the exercise sections of the chapters chosen. It was necessary to discard 16 tasks from the analysis when ambiguity was encountered (for example, where a misprint made it difficult to interpret what a task required). Questions sometimes consisted of several parts and these questions were broken down and treated as multiple tasks.

[Table 2 near here]

Table 2. Number of tasks for each textbook series at each level

Coding

Each of the 7635 tasks was classified separately using the framework outlined earlier. This involved carefully considering the features (symbols, wording, context etc.) of a task and determining the likely solution methods that students would employ, in order to determine which PM objectives they addressed. The first author coded all of the tasks and at least one of the remaining authors also looked at each task independently. About 30% of tasks were classified by all three authors. The resulting classifications were compared after each group of tasks had been analysed. We then discussed the small number of discrepancies in classifications, with each coder giving his/her perspective, before coming to agreement on how the coding should be applied. Having clarified and resolved our coding, we made any necessary revisions and reviewed the existing classifications of previous tasks in light of these revisions, in order to ensure consistency throughout the analysis. This form of internal refinement and quality control is common practice for this kind of work (Yang & Sianturi, 2020; Hadar & Ruby, 2019).

Each task was given a unique identifier and all classifications and reasons for such classifications were recorded electronically. We used SPSS (version 23) to store the data and to create frequency tables and charts.

Results

Classification of the textbook tasks with respect to the Project Maths Objectives

Table 3 contains the results of our task analysis. We found that all tasks corresponded to at least one of the PMOs, and some tasks fulfilled more than one objective. Thus, the column percentages in Table 3 do not add to 100%. A quick glance at that table shows the very high prevalence of tasks that fulfil Objective 10: *Use appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions*. In contrast, very few tasks in any textbooks require students to select or devise a method to solve the problem. Indeed, apart from the relatively high incidence of *Objective 1: Explore patterns and formulate conjectures* tasks in OL textbooks, the proportion of tasks that address Objectives 1-9 is very low across the board.

[Table 3 near here]

Table 3. Proportions of Objectives in pre- and post- Project Maths textbooks

Comparison of textbook series

We considered whether each textbook series was addressing the PMOs in the same manner. Fig. 1 gives a comparison of the incidence of tasks classified as addressing each of nine PMO for the post-PM Higher Level textbook series. Objective 10 is not included in this figure because its high prevalence in comparison to the other nine objectives would impact on the scale. (The percentages of Higher Level tasks in each textbook series which were classified as achieving Objective 10 were as follows; Text C Higher Level had 92.8%, Text B Higher Level had 89.2% and Text A Higher Level had 84.7%.) Text A Higher Level had the greatest incidence of 7 of these 9 objectives, Text B Higher Level had the greatest incidence of the other two.

[Figure 1 near here]

Fig. 1 Comparison of the percentage of tasks classified in each PMO in the post-Project Maths Higher Level textbooks

Similar results were found when the Ordinary Level textbook tasks were analysed; Fig. 2 gives a comparison of the incidence of tasks classified as addressing each of nine PMO for the post-PM Ordinary Level textbook series. Objective 10 was achieved by the vast majority of tasks (94% of tasks in Text A, 90.2% in Text B and 86.6% in Text C), and the percentage of tasks achieving the other objectives was very low, with Text C having the greatest incidence of 5 of these (namely, Objectives 3, 5, 7, 8 and 9), Text A having the greatest incidence of 2 (Objectives 4 and 6) and Text B of 2 (Objectives 1 and 2). Indeed, a key finding of our analysis is that the incidence of the other nine objectives is very low across the three textbook series.

[Figure 2 **near here]**

Figure 2: Comparison of the percentage of tasks classified in each PMO in the post-Project Maths Ordinary Level textbooks

When we considered the tasks from the textbooks in use *before* the PM syllabus reform, we found that an analogous pattern emerged in that Text A had the highest percentage of tasks in five objectives at Higher Level while at Ordinary Level it was Text C with four, all of these percentages were less than 9%.

Comparison of Higher Level and Ordinary Level Textbooks

From Table 3 we see that there are not many significant differences between the proportions of tasks which address each PM objective in the HL and OL textbooks. Indeed, if we consider the post-reform textbooks we see that the OL textbooks actually have a higher proportion of tasks which address Objective 1: *Explore patterns and formulate conjectures* and Objective 2: *Explain Findings*. The HL books do contain more tasks which involve Objectives 5, 6, 8, and 9. Perhaps this is because these latter objectives focus on students creating or selecting solution methods for themselves and/or applying their knowledge to non-routine questions posed in various contexts.

Comparison of textbook tasks from the Pre- and Post-Curriculum Reform Eras

We have seen that many of the Project Maths Objectives were mentioned also in the previous (DES/NCCA,1992) syllabus documents so it makes sense to study the incidences of tasks that address the PMOs in the old and new textbooks and to consider whether the new importance given to these objectives is reflected in the current textbooks. Table 3 shows that there is an increase in the incidence at both Higher (HL) and Ordinary (OL) Level of eight objectives moving from pre- to post- PM eras. There was a decrease in objectives 8 and 10, with objective 8 falling from 3.85% to 3.14% overall (i.e. when HL and OL are combined), while objective 10 records a decrease from 95.42% to 89.46% overall though it is still by far the most frequently observed objective in textbook tasks at both Higher and Ordinary Levels. It should be noted that even in the textbooks produced after the reform, the vast majority of tasks do not address the development of any of the problem-solving or synthesis skills listed in Table

1 apart from Objective 10. The proportions of tasks that address the first nine PMOs are very low and range from 1.41% overall for Objective 3 to 9.7% overall for Objective 1.

Discussion

As Usiskin (2013) explains, textbooks can act as a vehicle for curriculum change. He describes how, in many instances, it was not the publication of a revised curriculum which enabled change to occur but rather the appearance of textbooks manifesting the reform ideas. Sievert et al (2021; 2021b) have shown that the approach taken by a textbook can have profound implications for students' learning and understanding. Due to the established role of the textbook as a source of tasks (PDST, 2020; O'Keeffe & O'Donoghue, 2009), the three most popular textbook series in Ireland were studied using the lens of the PMO framework. Our purpose in this was to gather information on our two research questions.

Let us consider the first of these, that is: what proportion of the tasks in each of the textbooks address each of the Project Maths Objectives? We found that the most common Project Maths problem-solving objective encountered in all three textbook series at both levels involves the *use of appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions*, with a huge proportion of tasks (more than 85% in any one of the textbooks examined) meeting this objective. We note that the use of models, formulae or techniques is aligned most closely with the procedural fluency strand of mathematical proficiency (Kilpatrick et al., 2002) or the demonstration of instrumental understanding as outlined in the pre-PM syllabus (DES/NCCA, 1992). From this perspective, it would appear that there were scant improvements with the rollout of the curriculum reform in terms of moving away from an over-reliance on the use of algorithms.

The objective *explore patterns and formulate conjectures* is also relatively common across the three series, although its highest incidence is 13.5% in Table 3, and it is likely that this is influenced by the particular topic of Pattern, Sequences and Series. We note that the post-PM Textbook B had a higher occurrence of this type of task than the other series at both HL and OL (Figures 1 and 2). By way of contrast, the objectives of *justify conclusions* and *communicate mathematics in written form*, in particular, are rarely addressed, being invoked by less than 2% of post-PM textbook tasks at both Ordinary and Higher Level. The rarity of the opportunities offered to explain findings and/or justify conclusions would make it difficult for learners to develop the adaptive reasoning strand of mathematical proficiency (as described by Kilpatrick et al. (2002)).

More generally, the results of our analysis suggest that the textbook tasks examined do not currently promote enough non-algorithmic and higher-order thinking. Routine tasks activate imitative reasoning processes (NCCA, 2012, p.10) and a prevalence of such tasks (as seen in the high proportion of tasks invoking Objective 10 in the textbooks examined here) may make students dependent on a predictable solution process and encourage them to engage in rote-learning. It is likely that they will become comfortable only with familiar situations, and risk being unable to transfer their skills to unfamiliar problems or to other subject areas. In such a scenario, opportunities to activate creative mathematical thinking processes, thereby developing a deeper conceptual understanding are missed. An increased emphasis on tasks calling for a model or technique to be devised (Objective 8) on the other hand, would require students to think flexibly and provide a space for creativity.

Comparing the post-PM textbooks suitable for students studying Mathematics at Higher Level with those for students at Ordinary Level, there were few significant differences. The PM syllabus describes the Higher Level course as being “geared to the needs of learners who may proceed with their study of mathematics to third level” and explains how “particular emphasis can be placed on the development of powers of abstraction and generalisation and on the idea of rigorous proof” (NCCA, 2012, p.11) for such learners. Thus, in order to provide stepping stones for the development of such powers, we might have expected the Higher Level textbooks to have significantly more tasks invoking Objectives 1, 2 and 3 (that is, exploring patterns, formulating conjectures, explaining findings and justifying conclusions), but this is not the case. However, the HL books do contain more tasks which involve some of the higher-order objectives; 6, 8, and 9 (that is, analysing information, translating into mathematical form, devising or selecting appropriate models or techniques), for instance. The syllabus also outlines how the Ordinary Level course is geared to the needs of learners many of whom “may go on to use and apply mathematics in their future careers, and all of them will meet the subject to a greater or lesser degree in their daily lives” and states that it must start by offering mathematics that is “meaningful” (NCCA, 2012b, p.11). Thus, it may have been expected that a greater emphasis would be placed on tasks addressing Objectives 6 and 7 in the OL textbooks, in order to allow students to develop an appreciation of connections between mathematics and real life (as well as within mathematics) in line with the expressed aspiration of the new curriculum (NCCA, 2012). Again, this was not the case.

Let us consider our second research question: how do the proportions of tasks in each PMO differ from before and after the curriculum reform? It is important to acknowledge that some progress has been made in the context of the curricular reform in that there has been some change in the types of tasks included in textbooks. While the most common Project Maths objective drawn on by tasks in all three textbook series both before and after the reform was the Objective 10 (concerning more than 89% of tasks overall, as seen in Table 3*)*, the percentage of tasks addressing this objective dropped by 6% in the interim. However, the increase in the percentage of tasks linked to the other objectives appears modest. Nevertheless, it is important to note that the number of such tasks added is often non-trivial. For instance, 129 tasks in the HL post-PM books were associated with Objective 6 while only 11 such tasks were observed in the pre-PM texts. Similarly, the number of tasks linked to Objective 9 in HL texts increased by 99. In cases where there had been no tasks at all addressing a particular objective in pre-PM texts (e.g. for Objectives 3 and 4 at OL), the inclusion of a significant number of tasks in the post-PM texts signals an important change in what is expected of students. Hopefully the inclusion of these different types of tasks will in turn broaden students' views on the nature of mathematics as a discipline, keeping in mind Johannson's (2003) assertion that "the textbook often determines what is school mathematics and what is mathematics, for teachers and students" (p.1).

Our finding that the textbooks have yet to fully embrace the goals of Project Maths and that there is still a tendency for exercises to emphasise the practice of skills and algorithms supports the earlier work of Jeffes et al. (2012), O'Keefe and O'Donoghue (2012) and Davis (2013). However, our work gives a more detailed picture of the efforts of textbooks authors to align with the new syllabus. We have been able to show that the textbooks have improved with respect to the Project Maths Objectives, but that they did not quite reach the aspirations of the reformed curriculum and we have been able to quantify the shortfall. A limitation of our study is that it is based solely on an analysis of textbook tasks and not on any observation of classroom activity. Students may be given alternative tasks by the teacher or be exposed to different activities not covered by the textbooks. It is quite possible that teachers will deviate from the content suggested by the textbooks at times. We acknowledge that our study of textbook tasks does not take into account the ways in which teachers might extend the material in practice, however, we believe that this information on the *potential* implemented curriculum is valuable. Our aim was to shed light on how the textbook tasks had changed to reflect the problem-solving and synthesis objectives of the Project Maths syllabus.

Fan and Kaeley (2000) hold the view that it would be challenging to bring about change in teachers' teaching methods without corresponding reform of the textbooks being used in the classroom. Thus, our findings highlight the obstacles that exist for the Project Maths curriculum to be realised effectively if further development of textbooks does not take place. However, Ireland is not alone in this phenomenon, specifically in the failure of textbooks to provide opportunities for higher order objectives to be realised (Herbel-Eisenmann,2007; Glasnovic Gracin, 2018). Therefore, this is an issue of which the international mathematics education community should be aware. Indeed, Bakken and Andersson-Bakken (2021) posit that textbook tasks in a given country are heavily influenced by cultural genre norms; they claim that this may explain why there is often little variation between textbook tasks in a given country, and why sets of textbook tasks are so resilient to curriculum change. We have seen both of these phenomena in our analysis of textbook tasks. Bakken and Andersson-Bakken (2021) put forward the idea that in order to effect change, new norms need to be established by educational leaders (such as those responsible for developing new curricula). This was the case in Turkey (Bayazit, 2013) where the educational authorities gave guidance on the kinds of tasks that should be included in new textbooks, and also had the power to officially approve such books. It may be that the relevant Irish authorities need to consider similar actions.

In summary, there has been some attempt to meet the Project Maths objectives in the textbooks considered here. However, our results indicate that more attention needs to be given to the design of tasks that meet the goals of Project Maths. If not, the more traditional mathematics classroom, where the emphasis is on the development of procedural skills rather than applying mathematics in real-life contexts or understanding mathematical concepts and how they interconnect, is likely to persist (NCCA, 2006). It seems that the affordances of a textbook to support the development of understanding and mathematical thinking (Fan et al., 2013) are being overlooked by the textbooks considered here. It will fall to the classroom teachers to find or create suitable tasks outside of these textbook series in order to make sure that the Project Maths curriculum is implemented fully.

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Table 1. Original/Amended list of Project Maths problem-solving syllabus Objectives

Original List	Amended List
1) Explore patterns and formulate conjectures.	1) Explore patterns and formulate conjectures.
2) Explain findings.	2) Explain findings.
3) Justify conclusions	3) Justify conclusions.
4) Communicate mathematics verbally and in written form.	4) Communicate mathematics in written form.
5) Apply their knowledge and skills to solve problems in familiar and unfamiliar contexts.	5) Apply knowledge and skills to solve problems in familiar contexts. 6) Apply knowledge and skills to solve problems in unfamiliar contexts.
6) Analyse information presented verbally and translate it into mathematical form.	7) Analyse information presented in written form and translate it into mathematical form.
7) Devise, select and use appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions.	8) Devise appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions. 9) Select appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions 10) Use appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions

Table 2. Number of tasks for each textbook series at each level

	Textbook name and Level						
Topic and period	Text A Higher	Text A Ordinary	Text B Higher	Text B Ordinary	Text C Higher	Text C Ordinary	Total
Pattern, Sequences and Series Pre-PM	316	317	199	175	298	263	1568
Differential Calculus Pre-PM	536	219	445	211	387	218	2016
Total Pre-PM	852	536	644	386	685	481	3584
Pattern, Sequences and Series Post-PM	325	351	194	236	360	368	1834
Differential Calculus Post-PM	566	296	437	235	471	212	2217
Total Post-PM	891	847	631	471	731	580	4051

Figure 1: Comparison of the percentage of tasks classified in each PMO in the post-Project Maths Higher Level textbooks

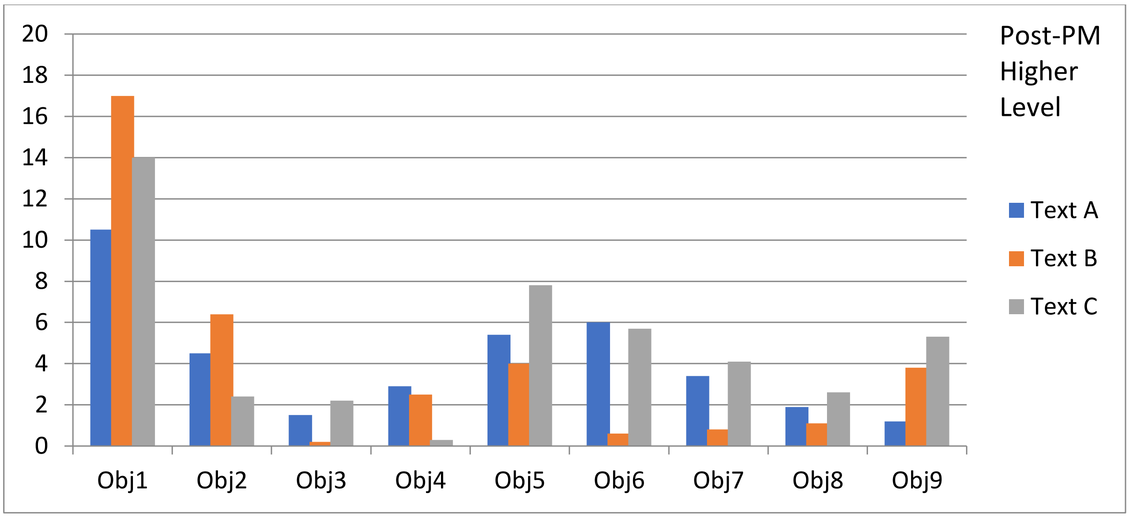

Figure 2: Comparison of the percentage of tasks classified in each PMO in the post-Project Maths Ordinary Level textbooks

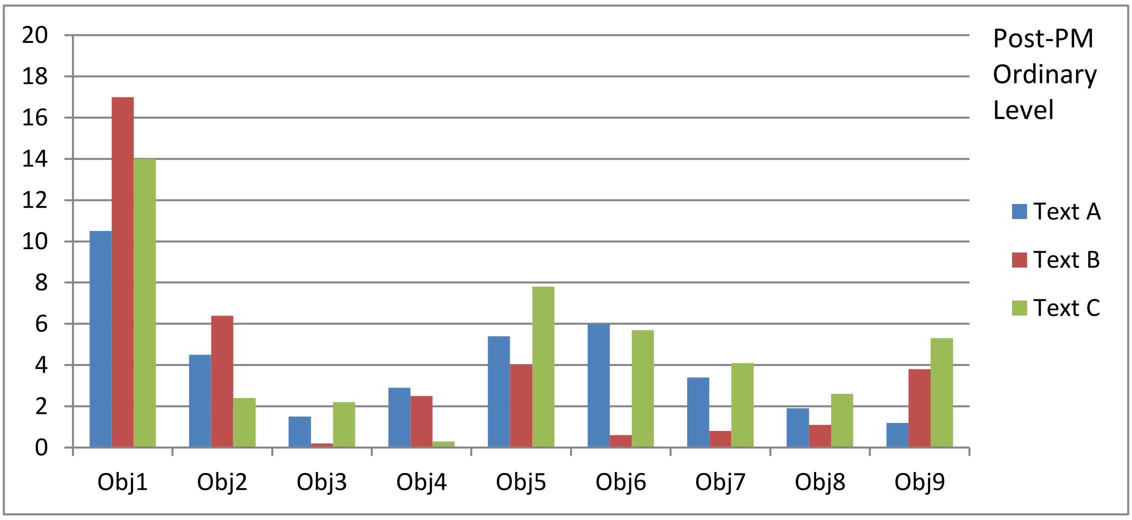

Table 3. Proportions of Objectives in pre- and post- Project Maths textbooks

Project Maths problem-solving syllabus Objectives	Pre-Project Maths OL textbooks	Post-Project Maths OL textbooks	Pre-Project Maths HL textbooks	Post-Project Maths HL textbooks
Objective 1 Explore patterns and formulate conjectures	126 8.9%	229 13.5%	76 3.5%	164 7%
Objective 2 Explain Findings	1 0.29%	73 4.3%	5 0.23%	51 2.17%
Objective 3 Justify conclusions	0 0%	24 1.4%	7 0.32%	33 1.4%
Objective 4 Communicate mathematics in written form	0 0%	33 1.9%	0 0%	37 1.6%
Objective 5 Apply knowledge and skills to solve problems in familiar contexts	37 2.6%	99 5.8%	105 4.8%	169 7.2%
Objective 6 Apply knowledge and skills to solve problems in unfamiliar contexts	1 0.29%	75 4.4%	11 0.5%	129 5.4%

Objective 7 Analyse information presented in written form and translate it into mathematical form	1 0.29%	42 2.5%	11 0.5%	65 2.8%
Objective 8 Devise appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions.	47 3.3%	32 1.9%	102 4.7%	95 4%
Objective 9 Select appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions	3 0.21%	57 3.4%	12 0.6%	111 4.7%
Objective 10 Use appropriate mathematical models, formulae or techniques to process information and to draw relevant conclusions	1353 96.4%	1535 90.4%	2067 94.8%	2089 88.8%
Number of tasks	1403	1698	2181	2353