FaSMEd Position Paper

Low-Attaining Learners in Science and Mathematics

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Introduction

This paper considers mathematics and science attainment in the context of the countries participating in the FaSMEd project, the full title of which is Improving Progress for Lower Achievers through Formative Assessment in Science and Mathematics Education (FaSMEd). The project aims to research the use of technology in formative assessment classroom practices in ways that allow teachers to respond to the emerging needs of low achieving learners in mathematics and science so that they are better motivated in their learning of these important subjects. This article explores the profile of likely underachievers in these subjects, drawing on the international literature. To begin with we will examine definitions or 'benchmarks' of *low attainment* which may be useful for the FaSMEd partners. We will consider two elements of low attainment, namely achievement and participation in STEM in schools before examining in more detail some of the causes of low attainment.

Before we consider these issues, however, it is worth noting that there is no universally accepted definition of the term 'low-attaining learner' (Tomlinson 2013) nor is there a clear profile of low achievers in the curricular subjects of mathematics and science. While such learners share the common feature of low achievement in subject tests, they typically hail in disproportionate numbers from disadvantaged social and/or cultural groups, and in some countries may also lack command of the first language of the classroom (Boaler, Wiliam and Brown 2000, Boaler 2005, Ireson and Hallam 2001). Internationally there has been considerable progress made identifying underlying cognitive mechanisms of children with learning difficulties and in particular mathematical cognitive deficits (Geary 2011, Geary, Hoard, Nugent and Bailey 2012, Geary 2013). Work on developmental dyscalculia, for

example, although at an early stage, may also inform our discussion on low attainment in mathematics (Kaufmann 2008, McLean and Rusconi 2014).

Consequently the multi-faceted causes of low attainment in different countries may be probed in new ways, capturing the structural, socio-economic, socio-cultural and cognitive factors that influence this. An exploration of all of these will provide insights on ways the FaSMEd project can address the issue of low attaining learners in our respective countries and serve as a model of practice for others.

Defining "low-attainment"

Students are usually identified as having low achievement in mathematics or science based on their performance on tests (Baker, Gersten and Lee 2002): these might be informal assessments designed by their teacher or they could be standardised tests or national examinations. Research carried out in the UK on effective teaching and learning for students in low attaining groups found that practices at school level differ for subjects, different year groups and school context, however, allocation of pupils to low attaining sets are based predominantly on prior attainment and perceived ability (Dunne, Humphreys, Sebba, Dyson, Gallannaugh and Muijs 2007).

Concerns have been raised about the methodology, contrasting results and possible flaws in the conceptualisation of large-scale pan-national assessments such as PISA (The Programme for International Student Assessment) and TIMSS (Third International Mathematics and Science Study), (Jerrim 2011, Sjøbergof 2007). Nevertheless these studies provide some benchmarks to classify low-achievement, and indeed these were the only explicit benchmarks in Mathematics and Science that we could find. Furthermore, and perhaps more importantly, they can be helpful for 'the insights we may gain into our own common practices' (Lee 2006, p166) as educational systems working together we aspire to generate pedagogic tools that will be effective in all our contexts.

In the PISA studies, achievement in mathematics is divided into six proficiency levels with Level 1 being the lowest and Level 6 the highest. (See Appendix 1 for a description of the six proficiency levels in mathematics). Students who do not reach Level 2 on this scale are considered to be a low-achiever by the OECD (2012) and by the European Council (Eurydice 2011, 18). According to the OECD (2010) students who do not reach Level 2 can carry out routine procedures according to direct instructions but struggle to work without help or in unfamiliar contexts. In PISA 2012, 23% of students from OECD countries did not reach Level 2 on the mathematics proficiency scale, while in 2003, 21.1% of students in OECD countries reached level 2 (OECD, 2004). The EU has set a target to reduce the percentage of low-achieving students (using the PISA scale) to 15% by 2020 (Eurydice 2011, 18).

Achievement in science is also divided into six proficiency levels in the PISA framework. (See Appendix 2 for a description of the scientific knowledge and skills which students possess at the various proficiency levels). In the 2012 PISA test 17.8% of students across the OECD countries performed below Level 2 on the science scale. Similarly, the EU has set a benchmark to reduce the proportion of 15-year-olds with low achievement in science to less than 15% in 2020 (Eurydice 2011). Admittedly, achievement in science is better than in mathematics with fewer students scoring at Level 2 (17.8% for science compared to 23% for mathematics). However, the percentage of low achievement in science has remained the same for 2009 and 2012 PISA results. Efforts to reduce the figures appear to date to have been unsuccessful.

When considering low attainment it is important to consider both achievement and participation especially in light of the link of STEM participation and achievement on future life chances. Work within Europe and the USA indicates that there are substantial problems with student engagement in science and mathematics (e.g. European Commission 2004; National Academy of Sciences 2007) and work within Europe suggests that interest in the sciences has declined in recent years (Bøe, Henriksen, Lyons and Schreiner 2011). There is also considerable variation in the provision and uptake of STEM subjects in post-primary education. We define participation in science and mathematics in post-primary education to refer to students' decision to study those subjects, and also their decision concerning the level at which to study these subjects. There is concern internationally that fewer students are choosing to continue their studies in science and mathematics at university level (OECD 2006), with the decline in the numbers of physics graduates being particularly steep. This concern is also linked to a concern around skill shortages to meet the needs of engineering, science, technology and mathematics, which are particularly 'acute' (Government of Ireland 2012).

Achievement in TIMSS and PISA across FaSMEd countries

In PISA 2006 the average mean mathematics score among OECD countries was 498. Of the FaSMEd countries the Netherlands had the highest score of 531, well above the OECD average. England, France, Germany, Norway and Ireland did not differ significantly from the average, while Italy differed significantly with a mean score of 462 (Baldi, Jin, Green and Herget 2007).

In PISA 2003 gender patterns in mathematics across OECD countries were fairly consistent, with 15-year boys generally outperforming their female peers. Gender performance gaps were visible for all FaSMEd countries with the exception of Norway and the Netherlands (OECD 2004). In 2012 across all the countries participating in PISA, the percentage of students achieving Level 2 or below was slightly higher in girls than in boys (23.6% and 21.3%, respectively), while a higher percentage of boys obtained mathematics proficiency scores at Level 5 or above compared to girls (14.7% and 10.6%, respectively) (OECD 2014). In PISA 2012 also the proportion of students performing below Level 2 in mathematics in Ireland (16.9%) is similar to the corresponding proportions in Germany (17.7%), while in some other participating FaSMEd countries such as United Kingdom (22%), France (22.4%), Italy (25%) and Norway (22.3%) slightly more students reached this proficiency level in mathematics. Shanghai China had the lowest percentage of students performing below this level (3.8%).

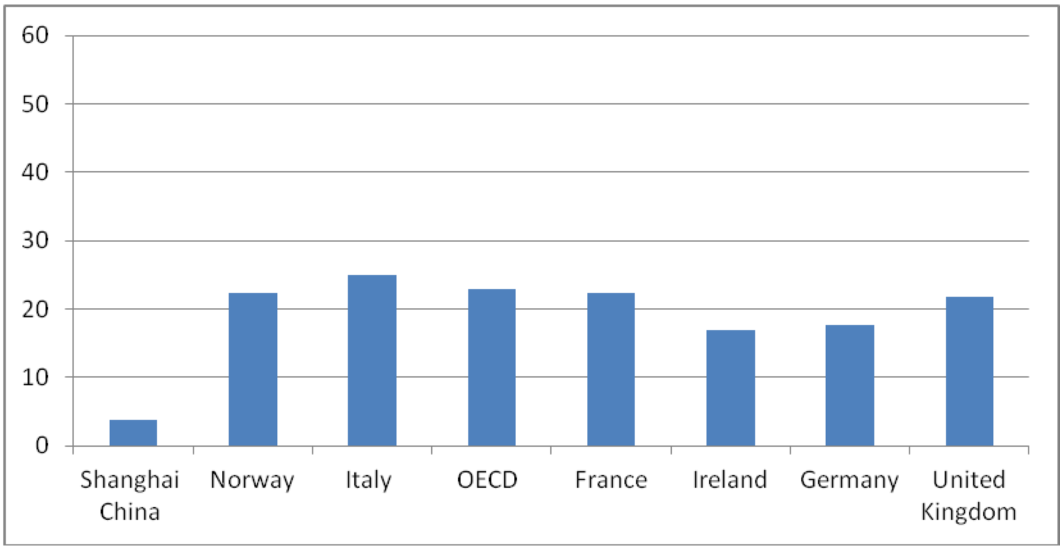

Figure 3: Percentages of students performing below Level 2 on the overall print mathematics scale in selected countries/economies and on average across OECD FaSMEd countries.

Among the FaSMEd countries the Netherlands had the highest mean science score of 525 in the 2006 PISA results, with Germany, United Kingdom and Ireland having scores significantly above the OECD average (Eivers, Shiel and Cunningham 2008, OECD 2007). Boys and girls showed little or no difference in average science performance in the majority of countries, including 22 of the 30 OECD countries. Where differences did occur most of them were small (OECD 2007).

Looking at low achievement in science, 11.1% of Irish students achieved a science score below Level 2, and along with United Kingdom (15%) and Germany (12%) this is considerably lower than the corresponding OECD average of 17.8% (OECD 2012). France (18.7%) and Italy (18.7%) shared similar results to each other where low achievement was recorded as being marginally above the OEDC average. Shanghai China had the lowest percentage of students performing below this level (2.7%).

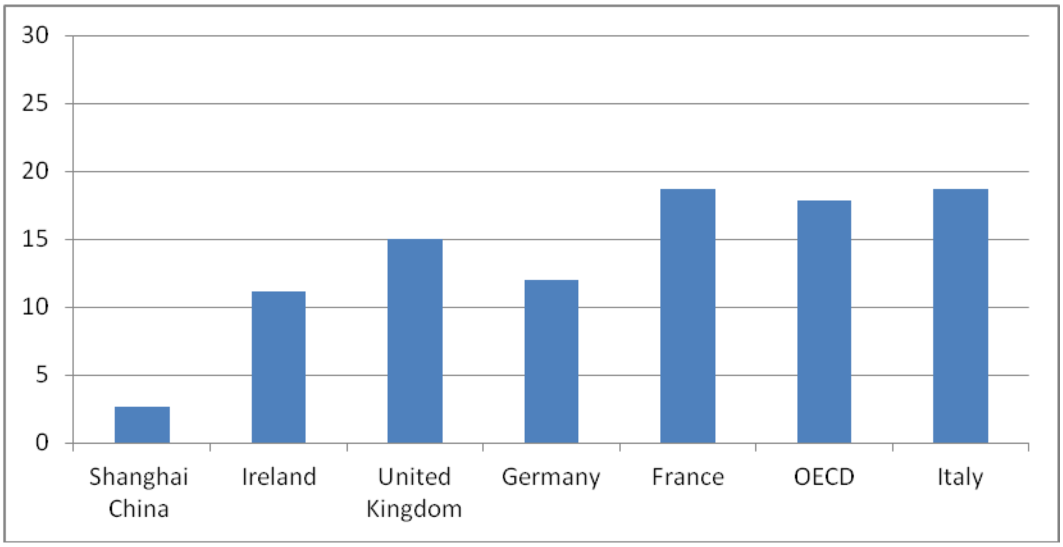

Figure 4: Percentage of students performing below Level 2 on the science scale in selected countries/economies and on average across OECD FaSMEd countries.

TIMSS is a large international study on mathematics and science achievement coordinated by the International Association for the Evaluation of Educational Achievement. Students are assessed at both primary level and post-primary level (Grade 4 and Grade 8 respectively). Whereas PISA attempts to look evenly at all 15-yar-olds in OECD countries the TIMSS tests examine students according to their grade level they have reached at school (regardless of age). The teaching and learning of mathematics and science comes under the microscope in

TIMISS, with members of the school community (students, teachers and school principals) providing information on this topic. This provides a rich array of information which describes the educational contexts for mathematics and science, including home environment support, students' backgrounds and attitudes, the curriculum, teachers' education and training, classroom characteristics and activities, and school contexts for mathematics and science learning and instruction (TIMSS 2011). Achievement is divided into four levels: advanced, high, intermediate and low. For example the description of the low achievement benchmark for Grade 8 students is “Students have some knowledge of whole numbers and decimals, operations, and basic graphs” (Provasnik, Kastberg, Ferraro, Lemnski, Roey and Jenkins 2012, p19).

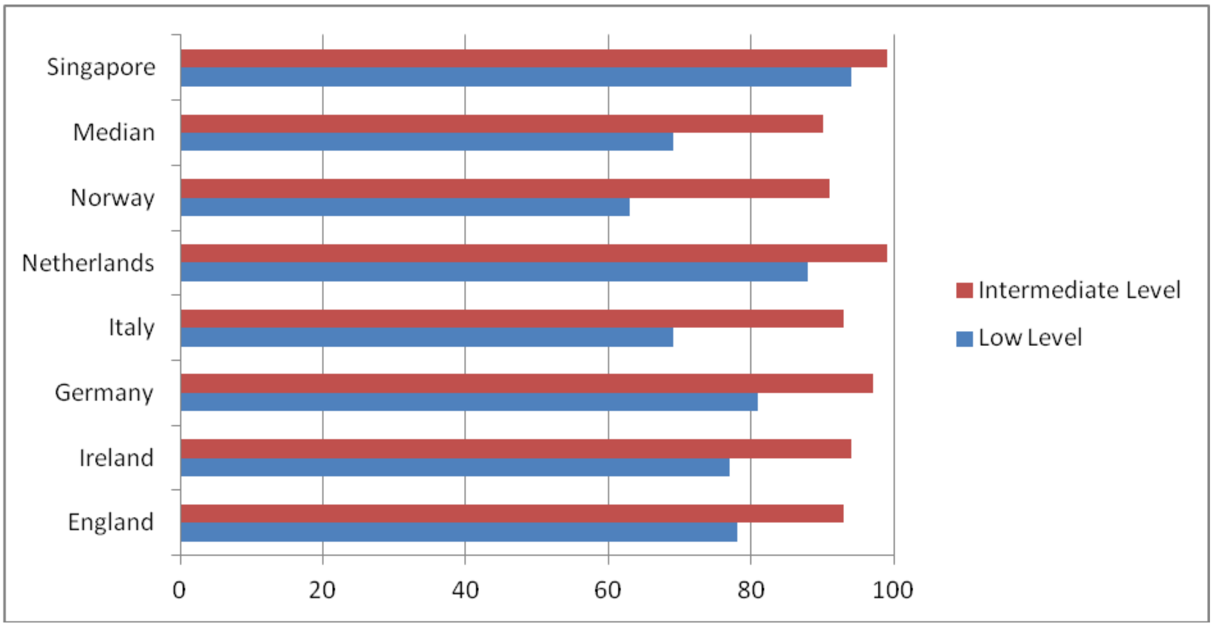

Figure 1: Percentages of students from participating FaSMEd countries performing at intermediate level and low level at Grade 4, TIMSS 2011.

In TIMSS 2011, it was seen that all participating FaSMEd countries scored above the international median benchmark (69% at intermediate level, 90% at low level) with only Norway scoring below the intermediate level median for mathematics at grade 4 (age 8-11). Singapore held the highest score with 94% of students performing at intermediate level and 99% of students performing at low level.

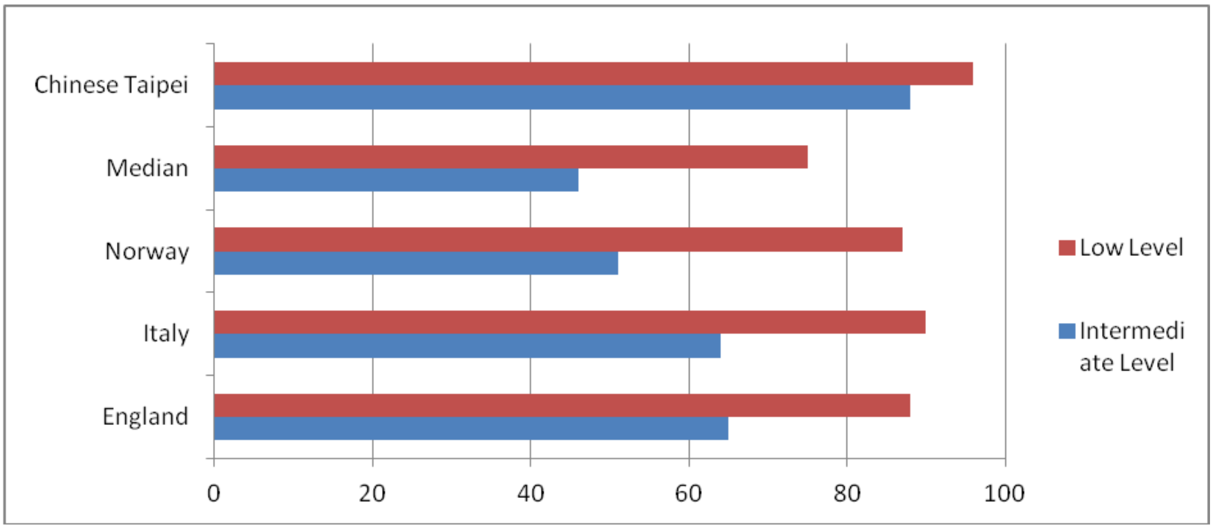

Figure 2: Percentages of students from participating FaSMEd countries performing at intermediate level and low level at Grade 8, TIMSS 2011.

In the same year students at Grade 8 (12-14) in participating FaSMEd countries performed above the median benchmark (46% at intermediate level, 75% at low level) with Chinese Taipei getting the highest score in this grade (88% at intermediate and 96% at low level).

It is important to note that the main evaluating difference between PISA and TIMSS is that while PISA assesses students at age level, TIMSS assesses students at two different grade levels. TIMSS assesses how much students have achieved in schools whereas PISA assesses how well students are prepared for the outside world (Lee, 2006).

Causes of and influences on low attainment

Low achievement in mathematics and science is considered a challenge across many OECD countries and notwithstanding the disputed accuracy and/or vested interests of the so-called "Global League Tables" that are PISA and TIMSS (Alexander 2010) attainment is recognised as being influenced by a complex system of inter-related student and school variables (Simpson and Oliver, 1990). International studies have indicated that student attitudes, student engagement, student self-concept, and previous educational attainment are all associated with performance in science and mathematics (see for example Chiu and Xihua 2008; OECD 2004 and 2007).

Educational research has also identified a number of other influences on attainment in science and mathematics, namely: home background (Morgan, Farkas, Hillemeier and Maczuga, 2009); attitudes to mathematics/science (Hemmings, Grootenboer and Kay 2011); gender (Hyde and Linn 2006); school-level factors as well as education system influences such as subject participation. In addition as noted, there is a growing literature on cognitive factors that influence learning in mathematics and science (Geary 2013). Some authors would argue that ethnic minorities, females and poverty-stricken students are too frequently counselled out of STEM subjects rather than supported in their learning (Hansen and Gonzalez 2014, Roth and Barton 2004).

Magne (2003) advises that when thinking about achievement in mathematics, one should look at what he calls the *factor-interplay model*. He looks on mathematical knowledge as the dynamic interplay of *mathematical subject matter, individual activities and social opportunities* (p12).

Home background influences

Educational attainment levels and educational outcomes generally are considerably stratified by socio-economic background (Sammons 1995). Family socio-economic background sets the stage for students' academic performance both by directly providing resources at home and by indirectly providing the social capital that is necessary to succeed in school (Coleman, 1988). Research indicates that children from low-socioeconomic status (SES) households and communities may develop academic skills more slowly compared to children from higher SES groups (Morgan, Farkas, Hillemeier and Maczuga 2009). Children from low-SES environments tend to acquire language skills more slowly, exhibit delayed letter recognition and phonological awareness, and are at risk for reading difficulties (Aikens and Barbarin 2008) whereas children with higher SES backgrounds are more likely to be proficient on tasks of addition, subtraction, ordinal sequencing, and mathematics word problems (Coley 2002).

Parental involvement in students' education has been seen to have big impact on student achievement (See Jeynes 2007, Hara 1998). Parental involvement can be discussed under three main headings: parental involvement in the home; their involvement in relation to the school; and the influence of parents' own educational achievement on that of their children. Parental involvement can occur in the home as well as schools with parents becoming actively involved helping with homework, inculcating a positive attitude towards school, and discussing the importance of education in their children's lives. Sui-Chu and Willms (1996) examined parental involvement and the effects on eighth-grade (13-14 years) achievement relating to four different factors and found that school-related activities at home had the strongest relationship with academic achievement.

When it comes to school, the involvement of parents in their children's education is now widely accepted as desirable and even essential to effective schooling (Bronfenbrenner 1974 and 1979). According to Henderson and Berla (1994):

> the most accurate predictor of a student's achievement in school is not income or social status but the extent to which that student's family is able to:
>
> - Create a home environment that encourages learning
> - Express high (but not unrealistic) expectations for their children's achievement and future careers
> - Become involved in their children's education at school and in the community.
>
> (p160)

When parents become involved in their children's school they play a key role in supporting their child's academic attainment. Archer and colleagues concluded that 'children's aspirations and views of science careers are formed within families, and these families play an important, albeit complex, role in shaping the boundaries and nature of what children can conceive of as possible and desirable and the likelihood of their being able to achieve these aspirations' (Archer, Dewitt, Osborne, Dillon, Willis and Wong 2012, p 22). Studies have shown that when parents are involved children tend to achieve more, regardless of socioeconomic status or parents' education level. Students also generally achieve better grades and have better attendance (Olsen and Fuller 2008). Gilleece and colleagues highlight the importance of the allocation of resources beyond the school level to take into account individual level differences particularly, home language, home educational climate and cultural capital (Gilleece, Cosgrave and Sofroniou 2010). The education level attained by the parents is strongly related to student performance in all European countries, as well as the United States (Woessmann 2004).

Attitudes to mathematics and science

Evidence indicates that attitudinal factors on the part of both students and teachers can have a powerful impact on achievement. In mathematics, anxiety and stereotyping, for example, are known to have a significant impact on the performance of students and these factors can also have an impact on how teachers approach this subject, particularly in primary school where they may not be 'subject experts' (Malony, Schaeffer and Beilock 2013). It is not known whether similar factors impact on science, although students in scientific topics, which use a significant amount of mathematics, might be expected to exhibit similar problems. The ROSE (the Relevance of Science Education) project sheds light on factors of importance that affect science education across a total of 40 countries. This project is not a test for conceptual understanding of science contents; it focuses more on students' motivation and attitudes toward science and technology (Schreiner and Sjøberg 2004). Of the FaSMEd countries, England, Ireland, Norway and South Africa have taken part in, or are currently compiling data for the ROSE project (Sjøberg and Schreiner 2010).

According to a study carried out by Sjøberg and Schreiner (1995) the question as to whether a young person wishes to opt for a career in science and technology is closely related to the country's level of development. When students were questioned on what aspects of science and technology they wanted to learn about, it was found that opinions from students were firstly closely related to those from geographically neighboring countries and secondly related to their country's level of development. Overall, the ROSE results indicate that in general, young people express a positive view on science and technology and gender differences were negligible (Sjøberg and Schreiner 2005). The teaching and learning environment for STEM subjects has an influence on motivation with students preferring more inquiry-based instruction based on thinking strategies and constructive activities (Magne 2003, Minner, Levy and Century, 2010). The pedagogical aspects of science and mathematics teaching and learning will be dealt with in a parallel paper in this series.

Gender difference in science and mathematics

There is also a gender aspect to STEM participation in the Irish context, perhaps exacerbated by the predominance of single sex education in Ireland. For example in 2012, 75% of Irish students who took physics and 70% of students who took applied mathematics were boys (State Examinations Commission 2013). More single-sex boys' schools provide physics compared to single-sex girls' or coeducational schools (96.4% compared to 71% and 71.8% respectively). Furthermore, the percentage of candidates for national examinations in physics in single-sex boys' schools is considerably higher than in coeducational or single-sex girls' schools (21.8% compared to 19.3% and 7.8% respectively). In England the story is somewhat similar with girls not aspiring to continue with physics after the age of 16 due to lack of encouragement from teachers or families. For example in 2011 of all examination entries for boys at age 18 in the UK, 6.5% were in Advanced Level physics with the equivalent figure for girls being only 1.5% (Mujtaba and Reiss 2013).

Gilleece *et al*. (2010) examined student and school background characteristics associated with high and low achievement in mathematics and science using PISA 2006 results for Ireland. As with findings in other institutional contexts, significant differences are found in the distribution of high and low achievers. Boys scored significantly higher than girls on the mathematics scale in the 2006 PISA results in the majority of OECD countries. In mathematics girls were more likely to be low achievers while boys were more likely to be high achievers. In science, as in other OECD countries, there were no gender differences in attainment levels. Catsambis (1994) in the US did not find gender differences in mathematics test scores and grades in the transition from middle school to high school. They do however find that female students tend to have less interest in mathematics and less confidence in their mathematical ability. Furthermore, as with other research studies in the US, they find considerable ethnic differences in mathematics attainment. They conclude that ‘the major barriers to mathematics achievement for white female students are attitudes and career choices and for minority students of both sexes, they are limited learning opportunities and low levels of achievement’ (Catsambis1994, p199).

Gender differences in mathematics and science academic performance and gender differences in student perceptions of their ability in mathematics and science has also been highlighted in the international literature (see for example Catsambis (1994) and Ayalon (2002)). Gender differences in mathematics performance at earlier stages of the Irish education system have also been identified in terms of cognitive scores at age three, with males displaying significantly lower scores than females in both picture similarities and naming vocabulary tests (Byrne and O’Toole, forthcoming); mathematics performance at age nine, with females displaying lower mathematics performance than males (Byrne and O’Toole, forthcoming; Smyth 1999). There are also gender differences in educational attainment and progression through second level (Byrne and McCoy, working paper in progress).

Cultural factors

In the Irish context the underperformance of students from lower socio-economic backgrounds can be attributed to their less favourable experiences of schooling (see McCoy, Byrne, O'Connell, Kelly and Doherty 2010) but also key structural school organisation and process differences across schools including differences in school environment, sense of belonging and personal meaningfulness of the curriculum and access to the curriculum (Lyons, Lynch, Close, Sheerin and Boland 2003). Furthermore, given increasing migration, the linguistic background of students is predictive of achievement (Cosgrove and Cunningham 2011). The picture in Norway somewhat resembles this with immigrant students or students with immigrant parents scoring substantially lower on national examinations than Norwegian students. This gap is equally pronounced in mathematics where close to 44% of the immigrant pupils performed at the lowest level along with 38% of the pupils with immigrant parents (Henriksen, Østby and Ellingsen 2010).

Studies have also highlighted the under-representation and underachievement of some groups in mathematics participation in the US and in mathematics related careers (see Valverde 1984; Catsambis 1994, Hansen and Gonzalez 2014). Reasons for such have moved away from explanations at the individual level – such as lack of motivation or ability – and placed attention on a mismatch between the policies, practices, and attitudes of school personnel and the values, learning styles and curriculum needs of diverse groups in society. As a result, Valverde (1984) attributes the roots of under-achievement in mathematics to the following factors: language, curricular material and cultural bias, instructional method, teacher quality and cognitive learning style. Valverde (1984) recommends that mathematics concepts be presented in the language that students are most proficient in, while highlighting the availability of bilingual teachers. Furthermore, studies in the US have indicated that during the transition from elementary to middle school, mathematics achievement is lowest for groups underrepresented in careers in science, technology, engineering and mathematics (MDRC, 2014).

School level factors

At the school level, despite controlling for a range of school level characteristics (to include school sector, school size, and gender composition), Gilleece *et al*. (2010) found that only school level average socio-economic intake was statistically significant in their models, replicating the findings of Cosgrove and Cunningham, (2011) and Smyth (1999). That is, there is a social context effect whereby the average socio-economic composition of the intake of students in a school exerts an influence on achievement outcomes over and above individual social background (Raudenbush and Willms 1995; Willms 2002; Smyth 1999; Smyth and Hannan 2002). In the UK social class and special education needs were found to be significant predicator of set[1] placement with ethnicity and gender being a weaker predictor (Dunne et al 2007). According to Boaler lower sets have a disproportionate number of boys and students from lower-socio-economic groups (2005).

However, across OECD countries, there is considerable variation in the extent to which student achievement varies between schools, suggesting that there is considerable variation in the extent to which schools provide equitable outcomes for students, even with the same student intakes. In PISA 2006, the percentage of achievement variation that lies between post-primary schools in Ireland was considerably lower than the OECD average. That is, variation between schools was less than 20% for both mathematics and science (19% and 17% respectively), compared with OECD averages of 35% for mathematics and 33% for science (OECD 2007). Using Canadian data Xin Ma (2001) found that within-school socio-economic gaps were highly correlated with mathematics and science achievement.

Student learning is mediated by culture, language and other socially constructed factors; students are therefore best understood in relation to their environment (Moses 2001,Magne 2003, Dunne et al 2007, Boaler 2005, Bonner 2014). Therefore Bonner contends *teacher interactions with students, which are social and therefore culturally significant, have great impact on student identity development and perceived ability in mathematics* (2014, p 380). Bonner provides a framework for culturally responsive mathematics teaching, which emphasises the main pillars of this method. The teacher uses knowledge about students, mathematics, culturally connected mathematics, and content and is communicating in culturally connected ways, making mathematics accessible to students, communicating care to students, and allowing students to communicate in comfortable ways so as to build relationships and trust in the mathematics classroom. This framework could also be applied in the science classroom. Dunne and colleagues (2007) found that a number of key classroom strategies worked with low attaining students including the use of praise, treating mistakes as part of learning, careful questioning techniques, strongly developed assessment for learning

[1] Set refers to class groupings based on examination scores. In the Irish context this is called streaming.

practices, use of ICT, cooperative learning and paying attention to cultural sensitivities (2007).

Cognitive aspects

Many children have difficulties with some or most aspects of arithmetic (Dowker 2008). It is hard to estimate the proportion who have difficulties, since this depends on the criteria that are used (Mazzocco, Feigenson and Halberda 2011; Desoete et al, 2004200). There is no single type of mathematics disability. Dyscalculia refers to a condition that affects the ability to acquire arithmetical skills and a wide range of lifelong learning disabilities involving mathematics. Dyscalculia can vary from person to person. And, it can affect people differently at different stages of life. Geary (2013), referring to data from the United States contends that poor mathematical competencies are common among adults and result in employment difficulties and difficulties in many common day-to-day activities. He goes on to say that about 7% of children and adolescents have a mathematical learning disability (MLD) and another 10% show persistent low achievement (LA) in mathematics despite average abilities in most other areas. Children with MLD and their LA peers have deficits in understanding and representing numerical magnitude, difficulties retrieving basic arithmetic facts from long-term memory, and delays in learning mathematical procedures. These deficits and delays cannot be attributed to intelligence, but are related to working memory deficits for children with MLD, but not for LA children. Interventions that target these cognitive deficits are in development and preliminary results are promising (Geary 2013). In a study carried out by the National Council of Teachers of Mathematics (2007) it was seen that such interventions such as student think alouds and peer assisted learning activities were effective in teaching students with low achievement in mathematics. Dunne and colleagues (2007) identified a range ways to maximise the advantages and minimise the disadvantages of low attainment groups including the concentration of resources, customisation of curriculum and the learning environment. One of the most difficult things to achieve with low attainment groups is maintaining a balance between challenging the learner with the support provided. Assessment for learning and peer evaluation were identified as effective strategies for maintaining this balance (2007). However, Magne (2003) would see this form of cognitive labelling, such as dyscalculia, what he refers to as *behaviour deviation model* as lacking validity and sees mathematics learning as being a much more complex affair (p11).

Conclusion

We have drawn on the PISA and TIMSS results for science and mathematics as internationally recognised frameworks that define and measure achievement. While we acknowledge that there are many critics (Sjøbergof 2012) of using these data as a benchmark, they are the only data available for all participating countries and provide the only lists of criteria for low-achievement that we were able to find. Bonner (2014) cautions against focusing simply on high-stakes data relating to achievement gaps and warns that *this presents a narrow picture of inequities in mathematics education and does not capture the underlying issues and assumptions that fuel these inequities* (p378). To militate against this we present some literature on causes and influences on low attainment. These include home background, attitudes to maths and science, gender issues, cultural influences, school level influences and cognitive aspects to low attainment.

A significant danger in the creation and even the labelling of low attainment groups is that they are accompanied by a narrowing of the curriculum, a lowering of learning expectations, and/or a restriction of pedagogical styles when we know from research into teaching and learning that the opposite is needed (Dunne et al 2007). While many of the causes of low attainment are outside the scope of this project such as home background and some school level influences, the project can have a considerable impact on what happens in the classroom. The role of parents and guardians in supporting their child's learning will also need to be considered.

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Summary descriptions of the six proficiency levels in Mathematics

Level	**What students can typically do at each level**
Level 6	Students can conceptualise, generalise, and utilise information based on their investigations and modelling of complex problem situations. They can link different information sources and representations and flexibly translate among them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understandings along with a mastery of symbolic and formal mathematical operations and relationships to develop new approaches and strategies for attacking novel situations. Students at this level can formulate and precisely communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situations.
Level 5	Students can develop and work with models for complex situations, identifying constraints and specifying assumptions. They can select, compare, and evaluate appropriate problem solving strategies for dealing with complex problems related to these models. Students at this level can work strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characterisations, and insight pertaining to these situations. They can reflect on their actions and formulate and communicate their interpretations and reasoning.
Level 4	Students can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. They can select and integrate different representations, including symbolic ones, linking them directly to aspects of real world situations. Students at this level can utilise well-developed skills and reason flexibly, with some insight, in these contexts. They can construct and communicate explanations and arguments based on their interpretations, arguments, and actions.
Level 3	Students can execute clearly described procedures, including those that require sequential decisions. They can select and apply simple problem

	solving strategies. Students at this level can interpret and use representations based on different information sources and reason directly from them. They can develop short communications reporting their interpretations, results and reasoning.
Level 2	Students can interpret and recognise situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions. They are capable of direct reasoning and making literal interpretations of the results.
Level 1	Students can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They are able to identify information and to carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are obvious and follow immediately from the given stimuli.

(OECD 2012, p41)

Summary descriptions of the six proficiency levels in Science

Level	What students can typically do at each level
Level 6	Students can consistently identify, explain and apply scientific knowledge and knowledge about Science in a variety of complex life situations. They can link different information sources and explanations and use evidence from those sources to justify decisions. They clearly and consistently demonstrate advanced scientific thinking and reasoning, and they use their scientific understanding in support of solutions to unfamiliar scientific and technological situations. Students at this level can use scientific knowledge and develop arguments in support of recommendations and decisions that centre on personal, social or global situations.
Level 5	Students can identify the scientific components of many complex life situations, apply both scientific concepts and knowledge about Science to these situations, and can compare, select and evaluate appropriate scientific evidence for responding to life situations. Students at this level can use well-developed inquiry abilities, link knowledge appropriately and bring critical insights to situations. They can construct explanations based on evidence and arguments based on their critical analysis.
Level 4	Students can work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of Science or technology. They can select and integrate explanations from different disciplines of Science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and they can communicate decisions using scientific knowledge and evidence.
Level 3	Students can identify clearly described scientific issues in a range of contexts. They can select facts and knowledge to explain phenomena and apply simple models or inquiry strategies. Students at this level can interpret and use scientific concepts from different disciplines and can apply them directly. They can develop short statements using facts and

	make decisions based on scientific knowledge.
Level 2	Students have adequate scientific knowledge to provide possible explanations in familiar contexts or draw conclusions based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving.
Level 1	Students have such a limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and follow explicitly from given evidence.

(OECD 2012, p113)

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