Mathematics Self-Efficacy in PISA and Relevance to Teaching and Learning in Irish Classrooms

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The self-efficacy beliefs of students and their impact on school performance have been investigated in PISA studies across a range of areas, including mathematics. Self-efficacy refers to the beliefs one has in one's abilities and actions to produce desired outcomes. These beliefs influence students' behavioural, cognitive and motivational engagement in learning. They are a significant factor in dimensions of performance such as application, persistence and resilience in the face of challenges. Mathematics was a main focus of investigation in PISA 2012. Mathematics self-efficacy was strongly associated with mathematics performance at the country level. Countries with higher mean performance in mathematics were those where students are more likely to report feeling confident about being able to solve a range of pure and applied mathematics problems. The relevance of these findings to the teaching and learning of mathematics in the context of Irish classrooms is discussed.

Introduction

Students' beliefs about their abilities in specific domains of academic and school activities, their self-efficacy beliefs, are now widely recognised as a key factor in school performance (Bandura, 1986,1997; EACEA, 2011; OECD, 2003, 2013; Pajares, 1996; Usher & Pajares, 2008, Zimmerman, 1999). Since it was introduced by Bandura (1977), the concept of self-efficacy has received extensive attention from educational researchers interested in its role in students' academic and school performance. Perceived self-efficacy, the "beliefs one has in one's capabilities to organise and execute the courses of action required to produce given attainments" (Bandura, 1997, p.3) is posited as a key factor in the actions and efforts that people undertake across a range of areas, including health functioning and education.

As a fundamental part of his social cognitive theory, Bandura (1986) contended that unless people believe they can produce desired outcomes, they have little incentive to act or persist in the face of challenges. For this reason, how people behave can often be predicted more accurately by the beliefs they hold about their abilities, rather than by their actual abilities. This occurs because self-efficacy perceptions powerfully influence what individuals do with the knowledge and skills they have. This helps to explain why there is often a mismatch between people's behaviour and achievement and their levels of ability. Bandura (1977, 1986) advances a view of human functioning that gives a central role to cognitive, vicarious, self-regulatory and self-reflective processes. People are seen as self-organising, proactive, self-reflecting and self-regulating. How people interpret the results of their behaviour informs and alters their environment and the personal factors they possess. This is the basis of Bandura's concept of reciprocal determinism, the view that personal factors, behaviour and environmental influences interact in reciprocal fashion. In the classroom setting, for example, students' self-beliefs can be enhanced when students alter their thoughts

and emotions (personal factors), when their teachers use effective classroom strategies (environmental factors) and when students themselves improve their own practices of self-management (behaviour). Social cognitive theory is rooted in a view of human agency in which people proactively engage in their own development. Fundamental to this sense of agency is the fact that individuals have self-beliefs that enable them to exercise a degree of control over their thoughts, feelings and actions.

In the context of education, self-efficacy beliefs influence students' behavioural, cognitive and motivational engagement in learning and are a significant factor in dimensions of performance such as application, effort, persistence and resilience in the face of challenges. Self-efficacy beliefs operate through the mediating role they play in how people make use of the knowledge and skills they possess. While students with a high sense of efficacy tend to pursue more challenging learning goals and are more resilient in resisting adverse academic influences, students with diminishing self-efficacy can become caught in a downward cycle of academic underachievement, leading to unhelpful attitudes towards school and learning (Bandura, 1986, 1997). The PISA 2000 report, *Learning for Life* (OECD, 2003, p.8) noted that "The degree to which students believe in their own efficacy is the strongest single predictor of whether they will adopt strategies that make learning effective". In mathematics, while performing can well lead to an increased sense of efficacy, students with low levels of self-efficacy are at risk of underperforming even though they may have the ability. If students do not believe they have the ability to accomplish specific tasks, they are less likely to employ the effort and strategies required to complete tasks successfully. Thus, the lack of adequate self-efficacy contributes to student underachievement and can become a self-fulfilling prophecy (OECD, 2013).

Student Self-Efficacy Findings PISA 2012

Mathematics was a main focus area in PISA 2012. The study investigated a range of students' self-beliefs including mathematics self-efficacy, mathematics self-concept and mathematics anxiety. The results confirmed previous evidence that, while different mathematics beliefs are related, they are conceptually distinct. Mathematics self-efficacy refers to the extent to which students believe in their own ability to manage mathematical tasks effectively and to overcome difficulties. Students' mathematics self-efficacy was found to be strongly associated with mathematics performance at the country level. Countries with higher mean performance in mathematics were those where students are more likely to report feeling confident about being able to solve a range of pure and applied mathematics problems. Mathematics self-efficacy has also been found to be a predictor of students' selection of mathematics-related areas of study and careers with a significant mathematics component (Hackett, 1995).

For PISA 2012 (OECD, 2013), along with the completion of the performance tasks, students were asked to report on their level of confidence in doing a range of pure and applied mathematical tasks involving some algebra. The study reported that "The relationship between students mathematics efficacy and mathematical performance was strong in 2003 and

remained strong 2012 (a correlation of 0.5) on average, across OECD countries and for 23 countries and economies" (OECD, 2013, p.83). Across the countries, mathematic achievement is, on average, associated with an increase of 49 score points per standard deviation increase in self-efficacy– "the equivalent of an additional year of school" (OECD, 2013, p. 93).

Mathematics self-efficacy was also investigated in relation to students' gender and socio-economic status. The study reported that girls and socio-economically disadvantaged students are more likely to have low levels of self-efficacy than boys and socio-economically advantaged students. In relation to girls' self-efficacy, it was stated that "gender differences are striking when students are asked to report on their ability to solve applied mathematical tasks, particularly when the mathematics problem is presented in terms of tasks that are associated with stereotypical gender roles" (OECD, 2013, p.83). Disadvantaged students were also found to be generally less likely than advantaged students to feel confident about their ability to manage specific mathematics tasks. While these differences partly reflect differences in mathematics performance related to socio-economic status, they were large and statistically significant differences, even with comparing students who performed similarly in mathematics. Significantly also, mathematic self-efficacy tended to increase among countries where students had reduced levels of mathematics anxiety.

In Ireland, students' mean score on the PISA 2012 self-efficacy index was "not significantly different from the OECD average score" (ERC, 2013, p.12). Students in Ireland have similar levels of self-efficacy as the average student across the OECD. Also comparable with findings across OECD countries was that "male students (in Ireland), report significantly higher mean scores than females on self-efficacy [0.32 scale points higher]" (ERC, 2013, p.12). Students attending girls' secondary schools had significantly lower self-efficacy [by 0.34 points] than students attending boys' secondary schools (ERC, 2013, p.124). The study also reported that in Ireland "Students attending schools in the School Support Programme (SSP) under DEIS had a significantly lower mean score on self-efficacy [by 0.26 points] compared with students in non-SSP schools" (ERC, 2015, p.124)[1].

Student Self-Efficacy and Attainment

Recognising the role of self-efficacy beliefs in school and academic settings can contribute to our understanding of why there may be a gap between students' accomplishments and their actual capabilities. Efficacy beliefs impact on individuals' thought patterns and emotional reactions. The conversion of knowledge and abilities into proficient action is governed by self-referent thought, activated through an individual's cognitive, motivational and affective processes. Students with low self-efficacy may believe that the challenge is greater than it is in reality, a belief that limits their capacity to address the task demands in a successful manner. Individuals with high self-efficacy, in contrast, will tend to approach difficult tasks and activities with a higher degree of composure. While some

[1] The School Support Program under DEIS (Delivering Equality of Opportunity in Schools) is a national programme designed to ameliorate the effects of disadvantage in schools.

individuals can experience undermining self-doubt about capabilities they clearly possess, others may have confidence about what they can accomplish despite possessing modest skill. Thus, self-efficacy is concerned not primarily with the amount of skills an individual possess, but with what he or she believes can be done with these skills in different situations and contexts.

It is important to note that self-efficacy is not the only, or even the most important, influence on achievement outcomes. No amount of self-efficacy will produce a competent performance when the necessary skills are absent. Researchers have highlighted the issue of overconfidence and students' having a miscalculated sense of efficacy. Students who lack skills or understanding in a domain may also experience the additional challenge of not being aware of their limitations in the area in question. Moreover, researchers have drawn attention to the complex relationship between beliefs and achievement, suggesting a circularity, which may also be a cross-cultural phenomenon (Williams & Williams, 2010). Nonetheless research on self-efficacy, which has been widely investigated in education contexts for 40 years, continue to inform discussion on factors influencing students' academic performance.

In the learning context of the classroom, it is not solely the learner's experiences that influences his or her self-efficacy beliefs; rather, it is the interpretation and inferences that people make about experiences, situations and performances that cause efficacy beliefs to be altered. Bandura (1997) described four main sources of efficacy-enhancing experiences: mastery experience, vicarious experience, verbal persuasion, and physiological and affective states. Based on the work of Pajares (2008), Usher (2009) and Zimmerman (1999), teaching practices which attend to the sources of students' self-efficacy can be described as including:

- *Mastery experiences*: scaffolding the learning; breaking tasks into manageable steps and achieving incremental gains in learning; focussing on learning goals as distinct from performance goals; focussing on the process of learning and developing skills; viewing errors as a part of the learning; differentiated approaches responsive to individual needs; increasing student's capacity as an independent learner; fostering a sense of agency
- *Vicarious experience*: using peer learning and co-operative group work approaches; promoting collaboration and reducing the competitive orientation of the classroom; maximising the instructional function over the comparative function of peer models by focussing on skill development
- *Verbal persuasion*: encouraging students to develop their own internal standard for measuring progress; framing evaluative feedback as gains rather than shortfalls; persuading students that skills are acquired through effort and perseverance
- *Emotional and physiological states*: reassuring students when they are becoming overly anxious about challenges in learning mathematics; reducing time pressures and providing clear guidance in relation to learning tasks

Thus, in the mathematics lesson, while teachers cannot directly raise students' self-efficacy, they can provide opportunities for students to experience and interpret their learning in ways that facilitate the development of a sense of efficacy.

Self-Efficacy in Mathematics Classrooms in Ireland

Very few studies have examined students' self-efficacy in relation to mathematics in the Irish classroom context. Walsh (2013) investigated whether students' experiences of approaches to teaching and learning of mathematics in classrooms can facilitate the development of their self-efficacy beliefs in mathematics. Four schools, two primary and two post-primary, participated in the study that employed mixed methods to acquire both qualitative and quantitative data.

The study found that teachers endeavoured to support students in developing confidence in their abilities in mathematics. Teachers at both levels were conscious of the significant influence of students' level of confidence in the mathematics learning experience. Teachers reported using strategies to promote students' confidence, such as giving praise and encouragement and they provided individual and small group support to students experiencing difficulties. The study found, however, that a number of aspects of classroom practice inhibited opportunities for the promotion of self-efficacy (see below). Moreover, the concept of self-efficacy and its role in the learning and teaching experience were under-utilised and teachers referred to a limited range of strategies to enhance students' efficacy and confidence in mathematics.

Mastery experiences that serve as indicators of capability through the development of skills are the most influential source of efficacy information in the learning context (Bandura, 1997). The description of the mathematics lessons from the study data reflected processes that were, for the most part, teacher-directed. The students' voicing of dependence on the teacher in order to enhance their skills and gain confidence in mathematics was a recurring theme at both the primary and post-primary levels. Students' discussion about mathematics contained frequent references to "the book", "the page", "tests" "exams", "results" "grades", "right answers" and "wrong answers". Accordingly, students revealed a predominant focus on performance goals rather than learning goals (Elliot & Dweck, 1988), as evidenced in a persistent concern with getting "right" answers and doing well in tests and examinations. Self-efficacy theorists contend that to support students in developing a sense of efficacy it is helpful to focus on "learning" or "mastery" goals which identify the progress that has been made in gaining knowledge and skills. However, participating students and teachers in the study referred more frequently to results and levels of performance rather than progress and gains made from students' starting points. Consequently, there were limited opportunities for students to recognise and affirm progress in their own learning and to develop a sense of efficacy in relation to the acquisition of new knowledge and skills in mathematics.

Vicarious experience and verbal and social persuasion provide further potential as sources of self-efficacy in the learning environment. In this study students and teachers reported that groups were used in mathematics lessons, though co-operative and collaborative approaches were not a regular feature of classroom practice. Concerning students' self-efficacy in the school context, Bandura (1997, p.176) noted that the evidence indicated that both "performance attainments and favourable self-appraisals are best achieved through co-

operative effort that is organised to work well". Several features of co-operative learning approaches overlap with approaches to support the development of students' self-efficacy. These include: establishing and working towards agreed goals; support for increased co-operative as against competitive behaviour; and support for the group dimension, contributing to a sense of collective efficacy. The influence of vicarious experience is also at play, as within the co-operative framework students have increased opportunities to observe the work of other group members and identify peer models from whom they can learn and so enhance their own sense of efficacy. Thus, the infrequent use of collaborative group approaches limited opportunities for efficacy-enhancing learning experiences during such activities.

A key finding of this study concerned the latent and powerful role of social comparative factors on students' behaviour in the classroom. This was evidenced in students' reluctance to engage in help-seeking practices such,as asking questions, where their own possible weaknesses in mathematics could be revealed to their classmates. Apprehension about getting the "wrong answer", appearing "stupid", or being perceived as-less able than peers was articulated. Thus, the potent and potentially inhibiting influence of social comparison factors on aspects of the students' participation in the learning experience may reduce opportunities for the development of their sense of agency and self-efficacy.

Assessment practices were a critical element of the students' experience of learning in mathematics. Students' interpretations of the results and feedback from summative and formative assessment played a key role in the development of their self-efficacy in mathematics. The study found that assessment, particularly in the form of tests and examinations, was a central element of the experience of the participating students. While assessment for learning was an ongoing element of classroom practice, the preponderance of focus was on summative assessment processes. Standardised test scores were a key concern of the teachers in the primary schools. In the post-primary schools, the students' experience of mathematics was largely concerned with preparation for state examinations.

While teachers identified "lack of achievement" and "failure" as crucial factors in students' confidence, such experiences are relative to the evaluation of task performance. Usher and Pajares (2006, p.137), observed, from their study of the sources of the efficacy beliefs of students, that "academic feedback must be crafted with particular care to how it might be interpreted". When individuals doubt their abilities, they require explicit and frequent feedback on progress that provides them with repeated affirmations of their abilities (Bandura,1997).

The study found that for the post-primary student there is a significant relationship between students' attitudes to mathematics and their perceptions of mastery experiences and feedback in the classroom. Students who perceived themselves as supported in making progress in mathematics and receiving encouraging feedback indicated more positive attitudes to mathematics. These findings underscore the relevance of providing high-quality feedback to students to enhance efficacy and facilitate the development of positive attitudes to mathematics (Hattie & Timperley, 2007, NCCA, 2007). Overall, the study drew attention to

the role of self-efficacy beliefs in the student experience in mathematics. It also identified areas of convergence between the aims and approaches identified in self-efficacy research to support the implementation of learner-centred and co-operative approaches in mathematics education (DES, 2010; ERC, 2016; NCCA, 2007; Pajares, 2008; Stipek et al., 1998; Usher, 2009).

Conclusions

Raising students' attainment in mathematics has been a policy priority in Irish education for many years, particularly through the implementation of *Literacy and Numeracy for Learning and Life: The National Strategy to Improve Literacy and Numeracy among Children and Young People 2011-2020* (Department of Education and Skills, 2011). The STEM Education Policy Statement 2017-2026 (DES, 2017) has set out ambitious areas for action considered necessary to achieve an improved STEM (Science, Technology, Engineering and Mathematics) education experiences and outcomes for learners. The policy's vision is that students' learning experiences should nurture a range of qualities, including curiosity, problem solving and creativity, along with confidence and persistence. Substantial developments in the post-primary mathematics curriculum programme have been implemented over more than a decade. The revision of a new primary mathematics curriculum is well advanced (Dooley, 2019).

Students' performance in mathematics continues to be an area of attention in Irish education. National and international studies, including PISA, provide important sources of information in relation to progress. While in PISA 2018 the overall mean mathematics score of students in Ireland was 499.6, significantly above the OECD average of 489.3 (ERC, 2019), Ireland was not among the countries with the highest-performing students. Ireland's mean score ranked 16th of the 37 OECD countries. Ireland had significantly fewer lower-performing students than the OECD average. However, there were also significantly fewer students performing at the highest levels. The PISA reports (OECD, 2003; 2013) have provided substantial data on the influential relationship between students' self-efficacy beliefs and performance. Few research studies have been undertaken in this area in the Irish school context. Further investigation into how practices in Irish classrooms influence the development of students' sense of efficacy in mathematics would contribute to teachers' knowledge of this significant dimension of teaching and learning.

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