Four Factors to Consider in Helping Low Achievers in Mathematics

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In this paper, we propose and describe in some detail a framework for helping low achievers in mathematics that attends to the following areas: Mathematical content resources, Problem Solving disposition, Feelings towards the learning of mathematics, and Study habits.

Mathematical Progress and Value for Everyone

Although the field of mathematics education is now replete with research literature in many areas, there is, however, relatively scant research in the area of teaching mathematics to low achievers. One needs only to type “mathematics low achievers (or low-attainers or under-achievers)” within the search category of ERIC and you will find only a handful of recently-published articles on display. This is especially disconcerting under the ongoing concerns over the widening educational achievement gap and discussions over the urgent need to reach out to low- and under-achievers to narrow the gap.

In Singapore, a few researchers have recently committed themselves to this much-needed enterprise of closing the gap. The Low Attainers in Primary Mathematics project (for details, refer to Kaur & Ghani, 2012), and the Learning Support in Mathematics evaluation study (Cheam & Chua, 2009) are two examples. What is missing are design studies that aim for workable designs to help mathematics low-achievers in the Secondary levels. Mathematical Progress and Value for Everyone (MProVE) is a funded research project that sets out to help low achievers at the Secondary levels. The project team starts with the recognition that a complex confluence of factors contribute to students’ low achievement. It is not restricted to their difficulties with the traditional ‘content’ domain – the subject matter of mathematics is viewed as difficult to grasp and they lack good foundations in mathematical knowledge. Other factors that contribute towards or hinder mathematics learning include but are not restricted to the ability to think about one’s own thinking, learning habits, threshold for frustration, and feelings of confidence (e.g., Karsenty, 2010, Keijzer & Terwei, 2004). It is our stance that efforts that can result in sustainable improvements in the students’ achievement should take into consideration all these interacting factors that influence their learning. To help low achievers make long-term gains in learning mathematics, a literature review for MProVE suggests that it is also crucial to cater to their affective needs in addition to their cognitive needs. More specifically, MProVE attends to the following areas of students’ needs: Mathematical content resources, Problem Solving disposition, Feelings towards the learning of mathematics, and Study habits.

The holistic approach that we are proposing is not restricted to the lens through which we use to analyse student needs. It extends to the way we view the nature of student change within the complex social system inside schools, this being the interaction among

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the curriculum, the teachers (their beliefs, knowledge, and instructional methods), the assessment practices, and the leadership structures that are necessary to support productive practices to help low achievers succeed. We take the view that, in order to engineer an environment for low achievers to thrive in their learning, there is a need to redesign structures and practices at multiple levels within the school system.

The overarching goal of the project is to explore the principles and critical features of a design for enabling low-achieving students to learn certain Lower Secondary mathematics topics. It is to be a holistic model that incorporates the dual complexities of successful students' learning and workability within the school system. In addition to obtaining deep understandings of the way low-achieving students learn and how different components within the school system interact under this context, we aim to develop a workable design with a view of diffusing it to a wider reach of Singapore schools.

Academic portrait of low-achieving students in mathematics

> The students … have not done well in math in the past, so they are recognized as students who don't do well in math. Most of them don't feel confident in math ... They take it because they have to ... Many of these kids can't concentrate because of what else is going on in their lives.

The above extract is a quotation of a teacher from Cleveland, USA, as cited in Bruckerhoff (1991, pp. 167-169). Though separated by time and space, this portrayal likely reflects the sentiments of mathematics teachers all over the world who teach low-achieving students.

For MProVE research, we look for a more fine-grained academic portrait of these low-achieving mathematics students. While there are many anecdotal reports by teachers about the characteristics of low achievers, research reports, especially meta-analyses, are rare. We found two studies – one based largely on the Realistic Mathematics Education (RME) in The Netherlands, and the other based on a number of projects sited in Israel – that share common goals with MProVE.

Keijzer and Terwei's (2004) literature survey of mainly studies in the Netherlands on the functioning of low-achievers found the following (p. 12): Low achievers (i) often undertake long and complex searches and lack the metacognitive strategies to escape from solutions that work elsewhere; (ii) have problems with cognitive overload, especially in solving complex problems in real life situations; (iii) lack the flexible use of a rich and well organized, domain-specific knowledge base; (iv) lack the ability to use heuristic methods; (v) have difficulties in understanding more developed representations like schemata and models and also experience difficulties in developing mathematical language; and (vi) experience difficulties when there is a need for considering numbers as formal objects and there is no clear reference to the contexts that produced them. As a consequence, low-achievers are not always able to ask for the right form of assistance because it is difficult for them to explain what it is they do not understand.

Karsenty (2010) crafted a portrait of low-achieving mathematics students based on a number of research projects (including the '3U' curriculum project, the middle school classroom study on low-track students, the "Improving Mathematics Learning" project to establish clearer theory-practice links with regard to the issue of Secondary school low-achievers in mathematics, all sited in Israel) he participated in. He noted the following characteristics found among students who achieve poorly in mathematics (p. 4): short-lived memory for mathematical procedures; difficulties with reading and writing in a mathematical language; and impediments in using symbolic representations. Other observed characteristics are poor note-taking and homework habits and short concentration periods. Some low achievers in mathematics develop a negative self-schema, i.e., feelings of fear, stress, and resentment towards mathematics. Lastly, low achievers tend to view mathematics as an esoteric, unattractive subject, detached from their common sense.

Four Factors for Consideration

A characteristic common to both the studies by Keijzer and Terwei (2004) and Karsenty (2010) is the difficulty these students have with mathematical language, mathematical procedures, mathematical symbols, and mathematical representations. All these aspects are critical for students to be successful in school mathematics. The MProVE framework integrates these aspects on the assumption that treating them separately will mask the dynamic interactions amongst them. We class them under the heading of "mathematical content resources" (MCR) and propose that any attempt to help low-achieving students gain success in mathematics must attend to developing students' MCR. The use of this term is linked by Schoenfeld's (1985) reference to "cognitive resources" as necessary to successful problem solving. The replacement of "cognitive" by "mathematical content" is to highlight the domain-specific nature of the knowledge that is needed for working within the subject of mathematics.

The first, second, and fourth points in the list by Keijzer and Terwei (2004) all relate to difficulties low-achieving students have when confronted with novel mathematical problems. The use of "metacognitive strategies", "heuristic methods" and the ways to deal with "cognitive overload" are parts of the overall process of mathematical problem solving. To do so successfully, it is not sufficient that students possess MCR. Instead of relying solely on the teacher each time they face an unfamiliar problem, these students need attack strategies that they personally own to tackle the problems with a sufficient degree of independence. We term this ability to devise a way forward in dealing with mathematics problems as having a "Problem Solving Disposition" (PSD). The choice of the word "Disposition" is to highlight the overall vision of PSD as not merely a simple reduction to a set of 'problem solving skills' but rather, as being about students' high degree of self-agency in harnessing these tools appropriately whenever they are confronted with a mathematics problem.

Moving further away from the mathematics domain, and on the fringes of what is conventionally considered the cognitive domain, are the other observed characteristics such as poor note-taking and homework habits and short concentration periods mentioned by the Israel researchers. Alongside MCR and PSD which are directly associated with the subject of mathematics, helping low achievers become successful with mathematics must include attending to "Study Habits" (SH). These study habits may be generic across school subjects, such as the building up of concentration/attention spans and the development of homework schedules; or, they may be more specific to the study of mathematics, such as the use of mnemonic helps to assist in the memory of mathematical facts/procedures. The term "study" has over the years somehow taken on a rather negative connotation that is associated with purely memorisation or cramming of facts. We owe a debt to Lampert (2001) for reviving the old-fashioned use of the term "study" that highlights its more positive traits of purposeful sense-making, where students "apply their minds purposefully to the acquisition of knowledge or understanding of something" (p. 32). We take the view that when students study learning materials in this sense, they are actively engaging in mathematical work.

Moving even further away, and outside of the traditional cognitive domain, we need to attend to the affective domain of low achievers. To many of these students, mathematics is a “charged subject; it carries a heavy burden of negative experiences” (Chazan, 1996, p. 469) and hence the “feelings of fear, stress, and resentment towards mathematics” (Karsenty, 2010, p. 4). Clearly, teachers who are intent on helping students become successful in mathematics cannot afford to attend only to the cognitive demands of the subject; they need also to take into account the affective domain. We need to consider their “Feelings towards the Learning of Mathematics” (FLM): to help students pare down their stress/fear/frustration levels and increase their sense of confidence and interest.

While we articulate four domains that we need to attend to in helping the mathematics low-achievers, we are not claiming that they are easily separable when observing teacher practice or student learning. We acknowledge that when a teacher, for example, makes an instructional move, he/she can have in mind a number of these as goals of teaching. The purpose of introducing the language of MCR, PSD, SH, and FLM is not primarily to craft well-defined theoretical constructs to be analysed in isolation, nor is it to prescribe a theory of instruction; rather it is to provide sufficiently workable categories as starting points to facilitate curriculum planning and teacher development. In these enterprises, it is not realistic to highlight at once all the domains under discussion. The intended approach is one where we foreground a particular domain during curriculum design and teacher development at any one point in time while keeping the others in the background (that is, in operation but not as the primary goal).

Conclusion

In this paper, we set out the broad framework of MProVE that guides all the components of the project – curriculum design, assessment practices, teacher preparation, and classroom enactments. In particular, we propose that, to help low-achieving mathematics students improve on a sustainable basis, there is a need to attend to MCR, PSD, SH, and FLM. In the next stage of the project, we selected jointly with the project school a portion of the lower secondary syllabus where we examined how suitable factors – out of the four – can be suitably integrated in the teaching of the topic(s). In doing so, we intended to start with a domain of inquiry that is of a moderate ‘size’ – that is, in both the scope of content and the number of factors to attend to, they are manageable for productive discussion for the purpose of curriculum design and teacher development. Due to the obvious limitations of space, the findings of this stage of the project are reported in a separate symposium paper.

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