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Mathematical Progress and Value for Everyone (MProVE)

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KEY IMPLICATION

1. The Replacement Unit Strategy for curriculum redesign is a workable way forward for schools.

ABSTRACT

The aim of this study was to help NA students improve their learning of mathematics.

We found that the strategy of foregrounding one factor with only one other factor in each Replacement Unit[1] (RU) provided teachers with sufficient, and yet not overwhelming, scope when redesigning the curriculum. For efficacy, it is necessary to work through the plan-implement-refine design cycle more than once. Though time consuming and tedious, there is no shortcut because the critical elements of teacher learning and taking account of local patterns of student learning are complex processes.

INTRODUCTION

Mathematical Progress and Value for Everyone (MProVE) is a research project that seeks to help NA students improve their learning of mathematics, based on a framework that attends to the following areas:

- Mathematical Content Resources (MCR)
- Problem Solving Disposition (PSD)
- Feelings towards the Learning of Mathematics (FLM)
- Study Habits (SH)

We designed a workable model that helps NA students learn difficult Lower Secondary mathematics topics. This is a holistic model that incorporates the dual complexities of successful student learning and workability within the school system.

RESEARCH DESIGN

MProVE used "design experiment" as its methodological backbone. This methodology argues for the application of multiple techniques to study a complex phenomenon in education. As such, it permits the use of a range of methods such as participant observation, interview, video-taping, and paper-and-pencil testing to provide corroborative evidence for findings. In Gorard's (2004) words, "The emphasis [in design experiments] … is on a general solution that can be 'transported' to any working environment where others might determine the final product within their particular context." The envisaged outcome of MProVE was to produce a workable model that can be adapted to NA students in other Singapore schools.

The study focused on working closely with one Secondary School in Singapore to redesign

[1] The term "Replacement Unit" (RU) is attributable to Hoyles, Kent, Noss and Smart (2012). While working on designing an RU, we developed a redesign for an entire mathematics topic. This redesign involved restructuring of content and development of all the relevant instructional materials without changing the original allocated time for the unit.

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the NA curriculum with a view to theorising for subsequent diffusion to the NA curriculum innovation in other schools. All students in the first two levels of the NA programme were involved in the project. There were two classes at each level, making a total of about 140 students. Most of the teachers in the mathematics department were involved. This research demonstrated how curriculum change can be implemented, with appropriate tweaks (which is a feature of design research), for NA programmes in other Singapore schools.

The success of the design, however, rests not on the quality of the intended curriculum alone. Teachers play a vital role in ensuring that the implemented curriculum matches the goals of the redesigned curriculum. Thus, teachers' commitment and training was an essential element in this project. The phases of the teachers' preparation and participation process were:

- Phase 1 (initialisation)—building professional relationships with the teachers, including discussions with the teachers on the adaptations of the framework—MCR, PSD, SH, and FLM.
- Phase 2 (module design)—teachers and researchers jointly designing modules, including supporting instructional materials. These redesigned modules are called Replacement Units (RU).
- Phase 3 (module implementation)—teachers carrying out the design developed in Phase 2 in selected NA classes within the context of Lesson Study practices for professional development.
- Phase 4 (curriculum design)—broadening the module planning and implementation under Phases 2 and 3 to the design of the overall NA curriculum for the school. Repeated cycles of Phases 2 and 3 on other mathematical topics at different year levels are necessary before starting on Phase 4. Due to the exploratory nature of this project, Phases 3 and 4 were part of a follow-up study and were not included in the scope of this project.

Following the phases described above, the following mathematics curricula units for N(A) classes in the project school were designed, implemented, and reviewed:

- 1NA: Addition/subtraction involving negative numbers
- 1NA: Number patterns
- 2NA: Expansion and factorisation of quadratic expressions
- 2NA: Solving simultaneous linear equations with two variables
- 3NA: Indices

Data were collected in multiple ways: (1) Field notes from participant observation; (2) Survey questionnaires for participating students; (3) Interviews with teachers; (4) Interviews with selected students; (5) Video-recording of lessons, including teacher actions and classroom behaviour of selected students; and (6) Continual assessment of students by teachers.

KEY FINDINGS

We discuss the findings of two of the five RUs.

Findings from analysis of student data from the unit Number Patterns

In order to establish a basis for comparing the students' learning before and after our intervention, pre-and post-tests were administered. There was a mean gain of 2.02 marks from the pre-test to the post-test.

We were also interested in a group of 12 students who took Foundation Mathematics in primary school. The data indicated that these students were weaker in the pre-test, but later caught up with the Standard students in the area where the intervention was made. In the end of year mathematics test, the Foundation students (Mean = 53.04, SD = 22.56) performed worse than the Standard students (Mean = 65.57, SD = 14.74). Yet when a comparison of the two number pattern questions was made, which constituted 7 marks, the Foundation students (Mean = 3.50, SD = 2.50) performed no worse than the Standard students (Mean = 3.13, SD = 2.04). The data suggest that the intervention in this area helped the Foundation students catch up with the rest of the N(A) students.

Findings from Analysis of Student Data from the Unit Simultaneous Linear Equations

Study Habits (SH) was identified as a particularly important area for this topic. Since the intervention was to be carried out during one unit (extending across five 45 minute lessons), the focus was on one aspect of SH: Note-taking. The

goal was to help students build this skill as a way of becoming conscious of the thinking behind mathematical procedures. Other researchers have found that Note-taking influences academic success (Carrier & Titus, 1981; Kiewra, 1987).

Two Secondary 2 NA classes in the project school were taught this topic based on the redesigned unit. At the end of the unit, a test was administered to see how well students had learnt the skill of solving simultaneous linear equations with two variables. The four items in the test were similar to the ones they learnt and practiced in the unit. Initially, 77 students (38 from 2N1 and 39 from 2N2) participated in the test, but only 70 test scripts were collected and deemed usable.

Each of the four items in the test was marked as follows: "0" for blank or completely unproductive manipulation of questions; "1" for productive manipulation of equations, but without correctly solving for any of the variables; "2" for skills demonstrated for manipulation and obtaining a correct value for one variable; and "3" for skills demonstrated for manipulation and correct solutions for both variables. Thus a total of 12 marks could be attained for the test. Students were said to obtain a "pass" if they obtained 6 marks or more. The results are shown in Table 1.

The results of the post-test show that the students were able to perform the more complicated algebraic manipulations to solve simultaneous linear equations.

Summary response to Research Question 1

(Did the students who participated in the redesigned curriculum implementation develop positively in one or more of these dimensions—MCR, PSD, SH, FLM?)

As this project only involved one school and all the lower secondary NA classes participated in the intervention, the discussion of 'gains' is not necessarily in the conventional quantitative sense, as it is assessed based on data sources such as an in-depth inquiry into a student's work, based on their worksheets over a series of lessons, as observed by a teacher. Where relevant, the findings are also based on pre- and post- tests (as in the case of PSD) or post-unit tests (as in the case of SH). On the whole, for those units where the redesign and implementation were conducted, there was evidence of positive development in the areas targeted for improvement in the respective units: MCR, PSD, and SH (note-taking).

Table 1. "Passes" obtain by the two classes.

Results	2N1	2N2	Total
No. of students	32	38	70
No. of passes	29	31	60
Percentage pass	90.6	81.6	85.7

Findings from Analysis of Teacher Data

The teacher data consisted of teacher interviews and video recordings of their lessons. Their starting point prior to their involvement in each replacement unit (RU) was noted first. One way to understand the learning opportunities teachers' gained from the RU enterprise is through analysing their participation based on the "standpoints" they took. Two teachers (M and L) who participated in the unit discussion were chosen for this analysis. Both teachers adopted a new standpoint some time during the RU process: that of a learner of students' learning. Both expressed clearly how close and regular observation of students' work in class helped change their views about what students could accomplish in response to the instructional innovations. M described how the students "enjoyed" the lessons and were "empowered" through productive attempts at the PSD worksheet, and this contributed to her "buy-in". Similarly, L pointed out that observing how students were able to come up with their own solutions changed her views of how to teach the topic.

From a teacher development perspective, this is critical if the goal is teacher change. Thus, professional development efforts should carefully consider providing teachers (compelling) opportunities to use this observer-of-student-learning outlook in their design. However, it is naive to conclude that the mere observation of students will bring about the kind of teacher change evidenced by M and L. An important ingredient to translate teacher observation of student learning into committed instructional change includes sustained observation of productive student learning.

Some features of a RU that help provide this are:

- The need for a clear, coherent focus of study to provide a basis for team members to share common perspectives.
- While common goals are important, the study should not be so narrowly framed that it only attracts the interest of the teachers who are actually teaching the lessons; rather, it has to be expansive enough to allow different teachers—including supporting members—to explore perspectives that are guided by their own knowledge, beliefs, and goals.
- The unit of study needs to be broadened from a single lesson to a suite of tightly-knitted lesson modules, to allow teachers a wider space to locate and confirm recurring points of learning. This helps teachers view not just one-off occurrences, but also gain opportunities to reinforce learning which can lead to an embedding of innovations in their personal instructional practices.

Summary response to Research Question 2

(What are the critical features of a NA curriculum design that influence MCR, PSD, SH, and FLM?)

Taking into consideration the findings from analyses of the student and teacher data, the critical features of a NA curriculum design that influence MCR, PSD, SH, and FLM are:

- In curriculum design, MCR is combined with only one other factor—PSD, SH, or FLM—in each instructional unit. This provides teachers with sufficient and yet not overwhelming scope when redesigning the curriculum.
- To reach a point where an instructional unit carries the twin goals—efficacy and balance—and where fidelity of these goals can be realised in actual classroom instruction, there is a need to work through the plan-implement-refine design cycle more than once.
- Teacher development is an important component that should be carefully and deliberately structured into the curriculum planning and evaluation process.
- For teacher commitment and learning, there should be ample opportunities to observe student learning in close quarters, over a sustained period of the students' learning trajectory.
- The lessons within the designed unit should be deemed successful in helping students learn the required content.

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