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ORIGINAL ARTICLE

Supplementary mathematics among adolescents in Timor-Leste

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Abstract

Students in Timor-Leste schools have been grappling with mathematics acquisition since the nation's independence in 2002. Schools encounter scarcity of resources necessary to effect significant change and few other organisations have formally assumed this responsibility. Despite the recognition of the importance of mathematics in Timor-Leste, research in this area remains limited. This paper aims to examine the mathematics proficiency of 10- to 15-year-olds and evaluate the effectiveness of a supplementary tutoring programme designed to address learning gaps. Our findings reveal disparities in students' proficiency across various mathematical domains. Students demonstrate higher achievement in counting, arithmetic, and number patterns and less so in statistics, angles, and shape recognition. Proficiency in three-quarters of curriculum strands pertaining to cycle 1 (grades 1 to 4) is below 40%. In response to these challenges, a supplementary tutoring initiative for this age group conducted in Tetum language was evaluated. The programme utilised tailored worksheets and small group sessions and took place thrice weekly. Results demonstrated statistically significant improvements over a seven-month period. Students in the intervention group on average gained proficiency in 7.5 new content areas compared to a comparison group value of 1.7. Feedback from participating students underscored the value of incorporating worksheets alongside traditional teaching methods. This study highlights the pressing need to address mathematics education in Timor-Leste and underscores the potential role of supplementary programmes. Importantly, it underscores that solutions can arise from low-resource community-driven interventions.

Keywords Timor-Leste · Supplementary tutoring · Instructional design · Worksheets · Remediation

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Introduction

The public education system in Timor-Leste is facing challenges in qualitative terms. Students in Timor-Leste have significant learning gaps due to factors including high rates of teacher and student absenteeism, lack of resources, traditional teaching approaches in public schools, and high student to teacher ratios (The World Bank Group & Timor-Leste Ministry of Finance, 2021 (WBG & TLMF)). Whilst school enrolments have increased over the last two decades, educational outcomes remain low. A survey by Ernst and Young (2018) showed that the majority of employers were dissatisfied with the skillset and general knowledge of school graduates. The government of Timor-Leste's 2011 strategic development plan stated that without increasing resources to improve the quality of education, "the increase in enrolments—whilst welcome and essential—may come at the expense of educational quality" (Democratic Republic of Timor-Leste, 2011, p.15).

The purpose of this study is to survey the current mathematical skillset of early adolescents in Timor-Leste and evaluate the impact of a supplementary training programme in the Tetum language designed to address students' learning gaps. The afterschool programme in consideration takes a holistic approach to facilitate student-centred learning in the presence of a tutor-mentor. Students predominantly focus on mathematics and English, but also engage in other areas of learning. This paper focuses on the programme's mathematics component which uses an instructional design approach to set clear individualised goals based on an aptitude test, prepare relevant learning material in line with those goals, provide regular feedback, and continue to assess routinely against the set objectives.

In this paper, we apply a sociocultural theoretical lens coupled with a quantitative approach to gauge students' sentiments about the pedagogical approach of the programme. We survey students' feelings around the use of worksheets as a learning tool and use a pre- and post-test instrument to measure their proficiency on a set of 42 curriculum standards. Understanding these sentiments and performance outcomes within the sociocultural framework provides valuable insights into the effectiveness of the supplementary programme and its implications for educational practise.

This research is relevant to teachers and administrators in Timor-Leste to better value the contribution of low-resource supplementary student-centred learning programmes outside schools. Non-governmental organisations and independent educators may also draw insights from this study into the effectiveness and cost-efficiency of such programmes, aiding in the design and implementation of future initiatives.

Context of schooling in Timor-Leste

Timor-Leste is a newly formed nation situated in Southeast Asia with a population close to 1.3 million (Timor-Leste National Institute of Statistics, 2022) and a low human capital index (World Bank, 2023). The majority of the population

is under the age of 21 (United Nations Department of Economic and Social Affairs, 2023). Timor-Leste regained its independence in 2002 following a long history of colonisation by Portugal and Indonesia (Tweedie, 2019). The United Nations categorises it as a least developed economy, with a shortage of skilled people to meet the demands of its growing economy (World Bank, 2022).

The Timor-Leste public education system faces overcrowded classrooms, insufficient resources, high rates of absenteeism by teachers and students, and limited instructional hours (WBG & TLMF, 2021). The average class size in public schools is 57 students. This impacts pedagogic practise; teachers dominate the classroom space by carrying out over 90% of the talk (Quinn, 2013). When students contribute, it is often as a response to closed questions requiring short answers or in repetition of memorised phrases. Even hands-on teacher workshops struggle to shift lecture-style practises (Gabrielson & Barreto, 2014).

A complex language ecology complicates the educational environment. As well as there being 20 diverse indigenous Timorese languages (SIL International, 2024), the educational ecosystem is affected by its colonial and post-independence history. During Indonesian occupation, and up until a quarter century ago, Timor-Leste public schools operated in the Indonesian language. Since reclamation of independence in 2002, Timor-Leste adopted Tetum and Portuguese as their national languages (Constituent Assembly of East Timor, 2002), shifting the language of instruction at schools to Portuguese through legislation regardless of teacher abilities (Taylor-Leech, 2013). This shift to using Portuguese by teachers who were trained in Indonesian was met with friction which continues today (Language Magazine, 2023). The role of Tetum as an oral aid gradually formalised over the next few years until it became an official language of instruction for early elementary in 2007, and eventually a language of instruction for later schooling alongside Portuguese. By this stage, Portuguese was still used more frequently than Tetum in teacher talk (Quinn, 2013). Boon et al. (2021), drawing on other studies (e.g. Savio, 2016; Boon, 2014), concluded that Tetum was the most favourable language among the population for all communicative purposes, in some cases as the "most useful language for the future of the children and for the future of the country" (p. 118), whilst Portuguese was not rated favourably. In 2013, the government of Timor-Leste enacted a new policy to introduce mother tongues into the first years of primary education, beginning as a pilot in Lautém (Fataluku), Manatutu (Galoli), and Oecusse (Baikeno) with promising results (Caffery et al., 2014). This policy is gradually being extended. Most up-to-date estimates suggest that competency among the population of Timor-Leste is highest in Tetum language with a literacy rate in speaking, reading and writing of 62.5% (General Directorate of Statistics, 2015). Only 30% of the population is literate in Portuguese which is often people's third or fourth language.

Given the underfunded and underresourced education system in Timor-Leste, coupled with the linguistic complexity of the educational context, a key question is how to improve schooling outcomes in cost-effective ways. This study examines supplementary training outside of school as one potential solution.

Literature review

Supplementary training for students outside school, commonly known as *shadow education*, is a growing trend around much of the globe (Bray, 2023). Tutorials tend to favour academic subjects and mirror schools in content. The surge in demand, especially prevalent in East Asia, is attributed to high-stakes examinations and the competitive underpinnings of neoliberal values (Bray & Silova, 2006; Zhang & Yamato, 2018). Supplementary training attracts students for remediation or enrichment to improve academic outcomes and school performance. The demand for shadow education is greatest in high socioeconomic urban households (Kosunen et al., 2020; Mahmud & Kenayathulla, 2018; Pov et al., 2020) and among families who are dissatisfied with the quality of teaching in traditional school settings (Sieverding et al., 2019).

Private tutoring may have potential adverse effects on students if unregulated. An environment of heightened academic pressure may cause anxiety and mental stress (Vice Asia, 2022). It can increase inequalities and reduce incentives for quality teaching at schools (Zhang, 2023). However, supplementary tutoring, when administered judiciously—such as with a remedial focus and offered in lower-pressure settings like summer programmes—can improve academic outcomes and foster effective learning, particularly in mathematics (He et al., 2021; Pope, 2016).

In the 2018 Programme for International Student Assessment (PISA), Southeast Asian countries performed well below average in mathematical literacy among the countries taking part in the assessment (World Bank Group, 2018). On average, 59% of students in Southeast Asian countries scored below basic proficiency. The Southeast Asia primary learning metric (SEA-PLM) conducted in 2019 (United Nations International Children's Emergency Fund (UNICEF) & Southeast Asian Ministers of Education Organization (SEAMEO), 2020) measured performance of students in reading, writing, and mathematics across 6 countries, namely, Cambodia, Lao People's Democratic Republic (PDR), Malaysia, Myanmar, the Philippines, and Vietnam. For mathematics, most students in Vietnam and Malaysia achieved at a level expected of their age (Grade 5). Students in Cambodia, the Philippines, and Myanmar presented considerably lower outcomes. Of the 6 Southeast Asian nations, Lao PDR performed lowest with 33% of students performing at the lowest band: below descriptors. Whilst globally there is a trend between a nation's per student education spending and test performance, Southeast Asian developing countries performed lower than their education spending would predict, suggesting education funding needs to be spent more efficiently in these nations. One way to ensure higher efficacy is to use the mother tongue in instruction.

Teaching mathematics in children's first languages has well-documented benefits: children learn mathematics more easily (Clarkson, 2007; Matang & Owens, 2014; Silburn et al., 2011). However, in many post-colonial countries today, learning the dominant colonial language and learning in the dominant language are often taken to be among the main goals of schooling, particularly for the

access that this can provide to socioeconomic power (Malone & Paraide, 2011; Setati, 2008). English medium mathematics instruction occupies a particularly prestigious position globally. Whilst it may be favoured by parents who believe it will benefit their children once they reach university and help them access international communications such as internet materials, it is not necessarily effective if teachers and students do not already speak English (Hamam, 2021). For example, in 2003, Malaysia introduced a policy that mathematics and science be taught in English. Most Malay teachers had received their own education in Malay and were not prepared to teach in English (Heng & Tan, 2006). In 2009, Malaysia reversed the policy of teaching these subjects in English (The Associated Press, 2009). Papua New Guinea's elementary Cultural Mathematics Syllabus was originally intended to be implemented in local languages, but in 2013, language policy reversed in favour of English being the sole language of instruction (Department of Education Papua New Guinea, 2013). Language of instruction in mathematics remains a contentious issue in many countries. Irrespective of the language used, its acquisition remains highly important to policy makers including those in Timor-Leste.

Mathematics is a significant component of the Timor-Leste academic curriculum. It is seen as a tool to enable the resolution of daily problems involving mathematical thinking (Timor-Leste Ministry of Education, 2014). Learning mathematics is referred to as a "necessity" for every child (p. 85) as it nurtures informed and critical thinkers to "better interpret, intervene and understand the world in which we live" (mathematics programme for third cycle of basic education, as referenced by: Ferreira & Castro, 2020, p. 1). Ferreira and Castro (2020) highlight that mathematics is necessary for managing such public spaces as schools, involvement in the petroleum industry, building of infrastructure, development of the health system, and fostering cultural activities.

However, there is little dedicated research on mathematics education outcomes in Timor-Leste. A report by Silva et al. (2011) investigated the performance of 1200 grade 1 to 3 students in 65 schools of Timor-Leste on a number of areas in mathematics. It found low levels of understanding and numeracy skills and suggested that students would be unlikely to access curriculum requirements at higher grades. Whilst students were competent in recognising numbers, a large proportion of students could not respond adequately to manipulative and arithmetic tasks such as word problems, addition and subtraction and number sequences. Pereira et al. (2022) found that fifth graders made frequent errors in understanding questions related to the operation of multiplication and division of integers and Pereira et al. (2023) found that students of science and technology in their late teens lacked the necessary accuracy and consistency in their problem-solving approach, resulting in most answers on a multiple-choice test being wrong. Beyond these findings, there is no recent research on a broader segment of the student population across a wider array of mathematics domains.

In mathematics education, the use of worksheets has been a longstanding albeit controversial practise. Classroom teachers seldom reflect deeply on the impacts of worksheets on student engagement, comprehension, and overall mathematical proficiency. Use of worksheets in school instruction has been a subject of heavy scrutiny

(Ransom & Manning, 2013) since emergence of constructivist and progressive education and projected as a teacher-centred hand-out (Oko, 2022). The criticisms are against drill tactics which often disengage students due to being repetitive and at an inappropriate level of difficulty. Easy worksheets bore students and difficult ones hinder them from progressing. Routine monotonous practise disengages attention, which reduces the rate of learning. It ignores conceptual understanding over procedural knowledge (Lehtinen et al., 2017). However, worksheets provide an advantage of allowing students to work independently. Worksheets may be selected specifically for each student within their zone of proximal development to be engaging and tutor explanations provide the scaffolding. Contrary to solitary instruments, they provide an arena of discussion and social interaction with peers and the tutor. Worksheet design is an important determinant of effectiveness and much research has gone into investigating optimal designs (e.g., Sutama et al., 2021). Mathematics is a skill which requires deliberate practise for mastery (Lehtinen et al., 2017). Where worksheets are not used, educators demand this practise by directing students to carry out exercises from textbooks. In the context of Timor-Leste, where students do not own mathematics textbooks to take home, and digital resources are unavailable, well-designed worksheets in Tetum, individually handpicked for each student may hold some value.

Due to the legacies of the colonial history, the choice of language for instruction of mathematics in Timor-Leste is not straightforward. Silva et al. (2011)'s report recommended the production of mathematics workbooks in mother tongue as well as recommending ongoing support for teachers, daily academic exercises, group work, and involving parents in their children's education. Research is yet to evaluate the impact of these recommendations. Regarding language of choice when solving mathematics questions, students in Timor-Leste schools had a varied preference between one of three languages: Tetum, Portuguese, or Indonesian (Silva et al., 2011). Tomé et al. (2022) concluded from interviews and class observations that whilst Portuguese is a suitable language for teaching mathematics, it needs to be supported by Tetum instructions for greater comprehension. There is no research on using Tetum as the sole language of mathematics instruction at the middle school level. Addressing these gaps is essential for advancing equitable and effective mathematics education in Timor-Leste and substantiates the purpose of this study.

Theoretical framework

We apply Vygotskian sociocultural theory as a lens to better examine the relationship between language, culture, and cognition of mathematical ideas in the context of Timor-Leste. Sociocultural theory considers learning to be a social phenomenon mediated through social interactions that challenge thinking. This includes conversations that resolve socio-cognitive conflicts (Bertrand, 2003). This perspective considers the influence of cultural norms and values on the formation and expression of mathematical concepts and problem-solving thinking. An important aspect of the sociocultural theory is the zone of proximal development: one in which students are challenged to extend their reach with adequate scaffolding (Eun, 2019). Vygotsky

also emphasises the role of a "More Knowledgeable Other," who can assist a learner acquire new knowledge through interaction (Vygotsky, 1986). Learning should also be transmittable in a cultural context to be meaningful (Bertrand, 2003). These elements of sociocultural theory impact our research design.

Research questions

Considering the gaps identified in literature, this study investigates these three questions:

1. What is the current level of proficiency for each strand of the cycle 1 mathematics curriculum among middle-school students in Timor-Leste?
2. To what extent does a worksheet-based afterschool tuition programme conducted in Tetum affect students' proficiency of each strand of the curriculum?
3. To what extent do students value the use of Tetum worksheets for mathematics instruction?

Methodology

Project design

This study is part of a larger study investigating the effects of an after-school tutoring programme in Timor-Leste. The programme is designed for the context of Timor-Leste. In this context, school instruction time is limited to 25 h per week in shifts (Timor-Leste Ministry of Education, 2014); this allows time after school to participate in other activities without an undue pressure often attributed to private tutoring (Bray, 2009). The low socioeconomic setting of Timor-Leste prohibits the use of electronic devices for learning, ostentatious venues, and one-on-one tutoring. The programme therefore uses printed, but individually tailored material, runs in humble spaces including people's homes or under the shade of a tree, and takes place in groups after school. The programme addresses academic and socioemotional needs, takes a remedial approach, and is facilitated by a tutor-mentor who fosters a safe environment for learning. Whilst Portuguese is the primary language of instruction in schools, this programme is distinctive in utilising Tetum as the language of instruction.

The programme implemented a payment structure for sustainability. Students paid USD 0.50 per week for accessing printed material. Tutors received sponsorship for their labour at USD 150 per month for full-time employment, consisting of 40 students in four groups. Tutors on average received USD 12 per month for transport and internet credit. Sponsors covered funds for stationary and other occasional expenses.

Participants

The participants of this study formed two main groups: intervention and comparison. All participants were of Timorese descent, attended school, and were aged between 10 and 15. All participants spoke Tetum, however, mother tongues varied across mainly four languages: Tokodede, Idate, Tetum, and Mambae. Saturated sampling was used for the intervention group. A total of 247 students consisting of 156 female and 91 male participants consented to participate in the research and completed a pre-test. The programme was held in local neighbourhoods where tutors resided, which consisted of 9 localities, including 3 urban, 4 regional, and 2 rural areas in 5 districts of Timor-Leste. A total of 126 pupils in this group remained in the programme for the full duration of the study and completed a post-test. Of these, 81 students who were present on the day of survey after the post-test period completed a single cross-sectional survey. These students had been involved in the programme for approximately 8 months at the time of survey.

The comparison group consisted of 143 students from four schools in two districts. They were selected through non-probability sampling due to practical circumstances as each school responded differently to our selection criteria. The sample included 90 female and 53 male participants. It is unlikely that any of these students received any additional tutoring in mathematics beyond school. Only 39 students from this group completed a post-test. The decrease in the number of participants can be attributed to several factors, including an early graduation at one school, frequent student absenteeism, and family relocations. The marked reduction in post-test participation, combined with the selection criteria for the comparison group, means that this study cannot be classified as a controlled-group trial but rather as a quasi-experimental design. Whilst this limits the generalisability of the findings in relation to the programme's influence, it nonetheless offers valuable insights into the potential creative solutions to address the educational challenge of Timor-Leste.

Instruments

The instrument used to assess the mathematics abilities of middle school students was a test with 62 short-response questions printed on a single double-sided sheet of paper. Given that the majority of students are performing significantly below the curriculum level, it was necessary to design tests at a foundational level to accurately identify both their strengths and areas for improvement. In contrast, a curriculum-level test would have merely highlighted their deficiencies without providing insights into their existing capabilities. The test therefore included 40 independently assessed items relating to the elementary mathematics curriculum (Timor-Leste Ministry of Education, 2014) in the categories stated below. Reference to each curriculum outcome is encoded in the form MATX.Y.Z, where the letter X denotes grade level, Y specifies one of the four main categories, and Z depicts the unique code for a further subdivision of content into a total of 19 branches..

- Numbers (MATX.**1**.Z)
- Geometry (MATX.**2**.Z)
- Quantities and measures (MATX.**3**.Z)
- Organisation and data processing (MATX.**4**.Z)

Test questions assessed proficiency in curriculum content relating to grades 1 to 4. The rationale was to assess the extent that learning gaps on foundational content persist into middle school following the findings of Silva et al. (2011). Proficiency was defined as giving a complete and correct response. Only certain curriculum elements were selected for this study so the test would not be onerously long, and the question posed on each element only tested a part of the strand. The initial test was modified slightly for post-test to avoid the learning effect.

The test was developed through a series of iterations and field practise to ensure questions were clear and test formatting was appropriate. A review of the paper post data collection revealed that some questions contained knowledge areas better suited to grade 5 or beyond on at least one of the two tests. For example, a question on measuring using scaled instruments contained negative readings. Data from these questions were omitted for this study. Questions in which students were able to make a 50:50 guess for an answer, as in the case of identifying odd and even numbers were also eliminated. Therefore, 40 out of the original 47 questions, each relating to a curriculum sub-strand, were selected for analysis in this paper. These remaining questions covered a range of content in each strand for an overall picture of achievement on elementary content.

We also administered a single cross-sectional survey involving 12 scaled multiple-choice and 4 short-response items. The survey was designed with simple text and a 3-point scale for clarity and ease of reading in response to the age and literacy levels of the study participants. Two multiple-choice and two short-response questions of the survey relate to this study. These questions asked students whether they like using worksheets generally and to compare this with using the blackboard in a traditional teacher-centred approach. The survey also asked students how often they complete their worksheet-based homework as an indication of interest. One limitation of the survey question is the possible introduction of overestimation in performance due to the social desirability bias (Nikolopoulou, 2023).

Procedure

For the first part of this study, 390 students completed an initial test between August 2022 and May 2023 in 13 groups representing 5 districts of Timor-Leste: Dili, Liquiçá, Ermera, Manatuto, and Baucau. The test was administered during 2 h along with a linguistic test. Therefore, students had approximately 1 h to complete the mathematics test but were granted flexibility in their use of time. Time allocation was ample and most students completed their test prior to the time limit.

For the second part of the study, the intervention group participated in the supplementary tuition programme to receive outside school remedial tutoring. Students met in small groups of up to 15 with a facilitator up to three times each week for 2 h.

The programme also provided training in other subject areas including English, visual art, humanities, and computer basics. The facilitator acted as a tutor and mentor and visited parents on occasion. Regular field visits by the researcher and a monthly encounter of facilitators in a central location ensured ongoing training, reflection, and adequate preparation of classes. Out of nine tutors, one had a university qualification in teaching mathematics, another was a university education student, and the remaining tutors had high school diplomas with occasional informal training.

Instructional design was used to design the mathematics programme. Students received individualised mathematics worksheets based on areas where competency was lacking as demonstrated from an initial test. At times, they also received homework. Facilitators checked student work during each session and gave frequent feedback, explaining ideas individually, in small groups or as a large group depending on student needs. Hands-on games and activities were also sporadically used for strengthening mathematics skills.

A total of 126 out of 247 students in the intervention group and 39 out of 143 students in the comparison group, from geographically distinct localities, participated in both the pre- and post-tests, with no overlap between the two groups. The tests were performed in controlled conditions and were conducted on average 6.8 months apart for the intervention group and 7.4 months apart for the comparison group. Students' preference for using worksheets was gauged through a single-stage cross-sectional survey among participants from the intervention group. Facilitators read the questions aloud and students responded by selecting relevant options or giving extended responses in text.

We acknowledge some limitations in the research design. In assessing mathematical capabilities of students in Timor-Leste, the initial sample of students tested only included participants from 5 out of 13 districts. Individuals selected were not entirely random. The comparison group consisted of students from two schools in Dili and two schools in Liquiçá. Only one of the four schools adhered strictly to the requested selection criteria of a randomised sample. In one school, we later found out that top performing students were asked to participate in the research investigation to increase the school's prestige. The intervention group was also more academically inclined, because students with less academic abilities did not continue in the programme long enough to participate in the post-test.

Data analysis

For the first research question, namely, *an identification of performance in different areas of mathematics*, we calculate the percentage of students who were able to respond to each element of the curriculum correctly and completely on their pre-test. Results are grouped in relation to four broad areas of the national curriculum (Fig. 1) and 40 sub-strands (Table 4).

For the second research question, namely, *the impact of an individualised worksheet approach in Tetum language on mathematics achievement*, we compare the change in the number of elements of the national curriculum for which there was proficiency between the two tests and compare this to the comparison group. Box

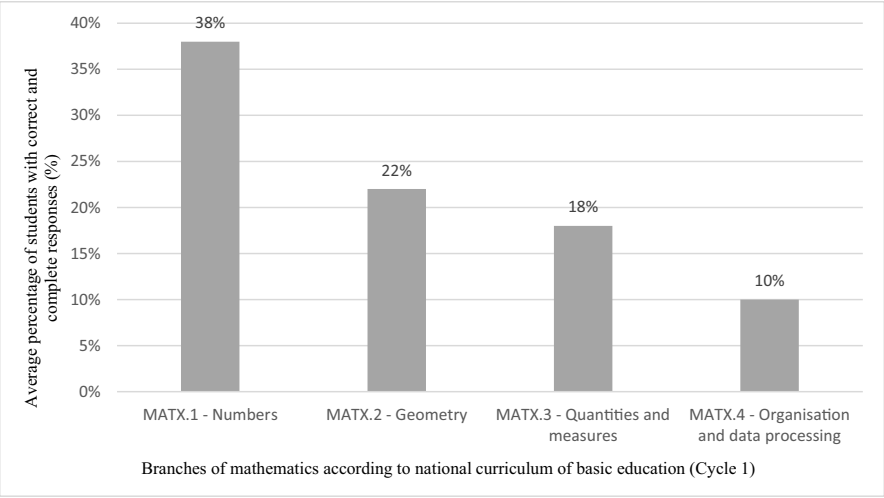


Fig. 1 Performance of middle-school students across the four main areas of the curriculum on cycle 1 content

plots for performance of all students in the intervention and comparison groups are displayed together for comparison in Fig. 2. To test the difference for statistical significance, a two-tailed Welch unequal variance *t*-test (Welch, 1947) is performed using Microsoft Excel (2016) with an alpha value of 0.01.

To measure the degree of influence of the programme on each subarea of mathematics curriculum, we propose two views. In the first view, the percentage increase in the number of programme participants who achieved proficiency for

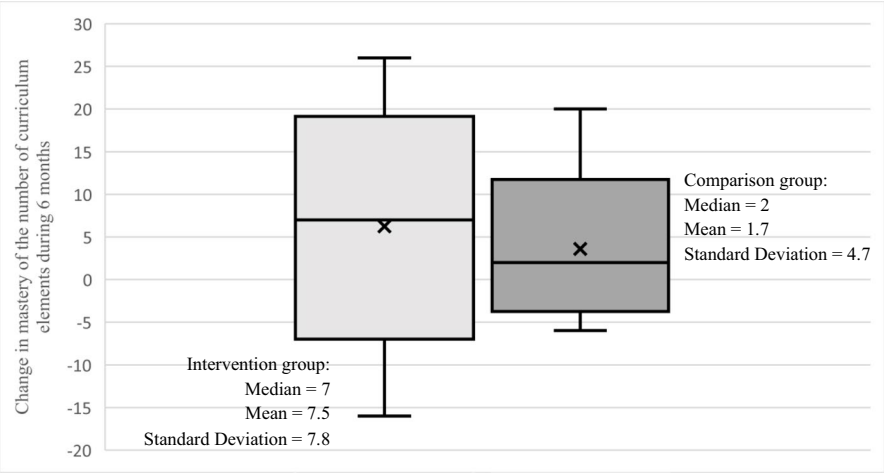


Fig. 2 Boxplots of the change in the number of strands of the national curriculum accomplished between pre-tests and post-tests in intervention and comparison groups

each content area is calculated. However, this view may be distorted for questions in which few people demonstrated proficiency in the initial test; even a single additional student achieving proficiency can result in a disproportionately high percentage increase, potentially misrepresenting the true impact. A more appropriate display of the impact is presented by the second view.

In the second view, we introduce an index S as a value within a scale ranging from $[-1, 1]$, where 1 indicates the programme's high influence and -1 indicates the programme's high negative influence. In this way, we can gauge the areas which were most influenced by Tetum worksheets. S is calculated as follows:

$$S = \frac{L-F}{n-F} \times (100\% - P) \times w$$

where n is the total number of students who sat the test ($n \geq 0$), 126 students completed both tests ($n = 126$); F is the number of students who knew this content in the pre-test ($0 \leq F \leq n$); L is the number of students who knew this content in the post-test (2F-$n \leq L \leq n$); P is the proportion of students who correctly answered this question on their first test (from the larger sample) ($0 \leq P \leq 1$), (100% - P) is a measure of the difficulty of the question; and w is the probability likelihood that students received the programme's worksheets as determined by the ratio of students who received these worksheets to total participants of the programme during the intertest period ($0 \leq w \leq 1$). Students were less likely to receive content at a higher grade level because they had to study lower grade content first.

Whilst the S statistic is unique to this study, we make note that it is merely a product of three parameters expressing new learning, question difficulty, and the programme's contribution. The $(L-F)/(n-F)$ is a ratio of students who learnt new content among those who did not know the content initially. This scale therefore accounts for individuals who learnt new content, of those who could potentially receive learning material on that content, and those who likely actually received that content and the level of difficulty of the question. We select a threshold for the S-index to evaluate the areas which were most susceptible to the influence of the programme. We consider a moderately difficult question ($p = 30\%$) which was foundational in content ($w = 85\%$) and on which 80% of students gained proficiency through the programme ($(L-F)/(n-F) = 80\%$). This gives an S-index of 0.2 as a threshold for narrowing down the curriculum strands in which the programme provided the greatest help.

The survey responses regarding the use of Tetum worksheets for mathematics instruction were analysed quantitatively. Two multiple-choice questions, assessing satisfaction with the worksheets and their usage outside of tuition hours, were coded using a 3-point scale, where '1' represented low satisfaction or infrequent use, and '3' indicated high satisfaction and frequent use. The number of students selecting '3' was recorded as an indicator of positive perception. Additionally, students' preferences for worksheets versus traditional blackboard teaching methods were compared. Students were asked to justify their preference through short-response items, which were reviewed for any notable comments. Given the brevity and fewness of responses, a formal analysis method was not applied. Instead,

relevant insights were noted based on recurring themes or interesting points raised by students.

Results and discussion

In response to the first research question, Fig. 1 summarises the average extent of proficiency for each area of the national curriculum by all students who consented to participate in the pre-test ($n = 390$). The analysis revealed notable patterns in achievement across the curriculum strands. Proficiency was highest for the *numbers* strand consisting of arithmetic, counting, and fractions. The lowest achievement was observed in organisation and data processing.

The breakdown of this information is presented in Table 1 using an alternative classification to the Timor-Leste National Curriculum. For example, unusually, in Timor-Leste *number patterns* (MAT3.2.2) is categorised as part of the *geometry* strand instead of the *number* strand. The difference between the *numbers* and *geometry* strands in Fig. 1 would be more pronounced if *number patterns* was instead categorised in the *numbers* strand as in most other curriculums. Table 1 presents students' achievements more distinctly for comparison with other curriculums. One implication of the contrast between student achievement in counting, arithmetic, and number patterns versus other knowledge areas is the need for teachers to appreciate the broader set of mathematical competencies, which require just as much attention.

Tables 2 and 3 provide sample questions from the test paper on which students demonstrated the highest and lowest achievement, respectively.

Table 4 contains a further breakdown of student achievement in relation to each sub-strand of the curriculum. Students performed best in simple arithmetic questions including addition and subtraction of numbers below 20, counting, understanding arithmetic symbols, and skip counting by twos. The areas of lowest achievement include questions relating to units of measurement, identifying angles in real

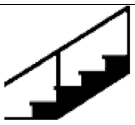
Table 1 Performance of 10- to 15-year-olds across subareas of the curriculum on cycle 1 content

Subarea	Percentage proficiency on test 1 ($N = 390$)
Counting	45%
Arithmetic	36%
Fractions	20%
Number patterns	46%
Features of shapes	18%
Angles	04%
Time	19%
Units and measurement	17%
Money	12%
Maps	22%
Statistics	10%

Table 2 Questions with highest levels of proficiency

Area of curriculum and code	Sample question
Addition and subtraction of numbers up to 20 – MAT 2.1.2	12 + 6 = 15 – 4 =
Addition and subtraction of numbers below 10 using shapes – MAT1.1.2	
Arithmetic operations using mathematical symbols – MAT3.1.3	(3 x 3) + 7 =
Counting (up to 100) – MAT1.1.1	43, 44, 45, _____
Recognition of sequences (skip counting by 2s) – MAT2.1.1	8, 10, 12, 14, _____, _____

Table 3 Questions with lowest levels of proficiency

Area of curriculum and code	Sample question
Identifying 90 degrees in real objects - MAT4.2.1	Identify 90 degree angles in the following shape: 
Converting minutes to seconds and vice-versa – MAT4.3.1	9 minutes = _____ seconds 180 seconds = _____ minutes
Using units to measure quantities – MAT2.3.1 (Distance) MAT3.3.3 (Weight)	Select an appropriate unit. Unit Weight Distance
Worded questions involving money and multiple-step arithmetic – MAT4.3.6	You go to the store to buy 4 pencils. Each pencil costs $1.20[a]. You pay $20. How much change should you expect?
Worded problems involving time durations - MAT4.3.5	School finishes at 3:30pm. You walk for 20 minutes. Then you catch a bus which takes 35 minutes to get home. You walk another 5 minutes to get home from the bus stop. What time do you arrive home?

[a]The United States dollar (USD) is the official currency of Timor-Leste. In addition to U.S. banknotes, Timorese coins are also in circulation, which are pegged to the U.S. dollar and feature local designs

objects, plotting graphs, converting units of time, identifying symmetry, time durations, and carry-forward addition and subtraction. None of the strands had a level of proficiency exceeding 70%. The implications of this are concerning when one considers the age group of participants to be in late primary or middle-school years. As many as 30% could not demonstrate an ability to carry out addition and subtraction of numbers below 20 or to count numbers below 100. As many as 96% were not able to competently convert between the units of time involving simple calculations

Table 4 Question-by-question analysis of test result in relation to curriculum strands for pre-tests, percentage improvement in comparison to post-tests among programme participants, and the programme's influence on the change of score (*S*)

Content description	Curriculum code	Percentage of students who answered completely and correctly on pre-tests ($n = 390$)	Percentage increase among programme participants ($n = 126$)	*S*
Numbers (MATX.1)				
Addition and subtraction of numbers below 10 using shapes	MAT1.1.2	69%	8%	0.07
Counting to 100	MAT1.1.1	66%	32%	0.17
Addition and subtraction of numbers up to 20	MAT2.1.2	70%	6%	0.04
Recognition of sequences (skip counting by 2 s)	MAT2.1.1	66%	34%	0.19
Working with numbers up to 1000	MAT2.1.1	47%	38%	0.13
Backward counting of four-digit numbers	MAT2.1.1	44%	84%	0.18
Dividing shapes into equal parts	MAT2.1.4	43%	58%	0.22
Identifying place values	MAT2.1.2	39%	85%	0.25
Using odd and even numbers	MAT2.1.1	28%	72%	0.06
Identifying representations of "half"	MAT2.1.4	22%	145%	0.28
Arithmetic operations using mathematics symbols	MAT3.1.3	59%	0%	0
Grouping objects	MAT3.1.3	34%	75%	0.28
Multiplication and division problems	MAT3.1.3	28%	33%	0.03
Number sequences (skip counting backwards by 3 s)	MAT3.1.3	27%	154%	0.20
Addition and subtraction (below 1000)	MAT3.1.2	18%	141%	0.14
Showing unit fractions using figures	MAT3.1.4	14%	160%	0.11
Carry-forward addition and subtraction	MAT3.1.2	9%	200%	0.18
Multiplication	MAT4.1.3	22%	57%	0.05
Division and multiplication involving two digits	MAT4.1.3	18%	33%	0.01
Mean ($\bar{x}$)	**MATX.1**	**38%**	**74%**	**0.14**

Table 4 (continued)

Content description	Curriculum code	Percentage of students who answered completely and correctly on pre-tests ($n = 390$)	Percentage increase among programme participants ($n = 126$)	S
Geometry (MATX.2)				
Using language of direction to move	MAT2.2.1	31%	48%	0.14
Identifying vertices, edges, and faces	MAT2.2.4	11%	136%	0.12
Identifying symmetry	MAT2.2.2	9%	200%	0.09
Completing simple numerical patterns	MAT3.2.2	48%	70%	0.14
Completing geometric patterns including rotation	MAT3.2.1–2	32%	−16%	−0.06
Identifying 90 degrees in real objects	MAT4.2.1	3%	250%	0.01
Mean ($\bar{x}$)	**MATX.2**	**22%**	**115%**	**0.07**
Quantities and measurement (MATX.3)				
Comparing lengths (smallest to largest)	MAT1.3.1	45%	39%	0.13
Identifying planar (2D) and solid (3D) figures	MAT2.3.2	25%	103%	0.34
Using units to measure quantities	MAT2.3.1 (distance) MAT3.3.3 (weight)	3%	300%	0.05
Comparing shapes using informal units	MAT3.3.2	14%	100%	0.01
Reading an analogue clock to the quarter-hour	MAT3.3.5	30%	39%	0.05
Using a calendar to identify dates and time	MAT3.3.5	29%	67%	0.09
Reading an analogue clock to the minute	MAT3.3.5	24%	94%	0.05
Worded questions involving money	MAT3.3.6	21%	0%	0
Counting money involving paper currency	MAT3.3.6	9%	475%	0.15
Worded problems involving time durations	MAT4.3.5	6%	150%	0.02
Worded questions involving money and multiple-step arithmetic	MAT4.3.6	6%	250%	0
Converting minutes to seconds and vice-versa	MAT4.3.1	4%	0%	0

Table 4 (continued)

Content description	Curriculum code	Percentage of students who answered completely and correctly on pre-tests ($n = 390$)	Percentage increase among programme participants ($n = 126$)	*S*
Mean ($\bar{x}$)	**MATX.3**	**18%**	**135%**	**0.08**
Organisation and data processing (MATX.4)				
Constructing simple graphs[b]	MAT2.4.1	2%	300%	0.02
Reading information from graphs	MAT3.4.1	16%	−35%	−0.03
Identifying familiar places on a map	MAT3.4.2	13%	375%	0.16
Mean ($\bar{x}$)	**MATX.4**	**10%**	**213%**	**0.05**

[b]For this question, marking criteria required students to display a complete graph with labelled axes. 2% achieved this task in its entirety. The percentage of students who made some attempt at constructing a graph is higher

and 97% were not able to identify the units of measurement for both distance and weight. We temper our judgments about the overall mathematical literacy of these young people with a few considerations. Some questions on the tests were posed outside the students' daily context. For example, scales to measure the weight of goods are not commonly found in local markets, and the term 'unit' (of measurement) may have been unfamiliar to them. Additionally, we recall that mathematical competencies acquired in out-of-school contexts do not always transfer to school test performance (Saxe, 1991). Therefore, whilst these results are alarming, they somewhat reflect the societal circumstances in which students live. These results call for targeted interventions and instructional support to address the identified areas of weakness and ensure a more comprehensive understanding of mathematical concepts among students.

Results for the second research question pertaining to the impact of the supplementary programme on student learning are also illustrated in Table 4. The programme had some positive influence on most curriculum strands, albeit to varying degrees. The areas of greatest impact ($S > 0.2$) mainly centre on geometric concepts. These include identifying planar and solid figures, grouping objects, identifying halves in shapes, and dividing shapes into equal parts. These results may indicate that the influence of worksheets is highest due to their ability to represent ideas visually. This was not the case where students generally achieved poorly ($p < 10\%$) on the initial test, as in the case of identifying symmetry. Although achievement in this area grew twofold in the post-test, the influence of the programme is deemed insignificant because the ratio of students who benefited from the programme was low amongst those who had the potential to learn this content area. It seems that the areas of greatest influence were at a moderate level of difficulty because not many students received material for easy tasks (many people already knew it) or hard tasks (we did not get there yet). These may indeed be areas most impacted by remedial training and may be valuable for the attention of educators.

We consider the overall impact of the tutoring programme on gaining proficiency in new curriculum areas compared to a comparison group. Following a Welch *t*-test (1947), the absolute value of the *t*-statistic (5.97) is greater than the *t*-critical value (2.63). Therefore, the null hypothesis of no difference between the two datasets is rejected and we conclude that the tutoring programme results in statistically significant academic gains for students in the supplementary programme ($\alpha = 0.01$). Figure 2 contains boxplots of the change in the number of elements of the national curriculum which were correctly and completely answered between pre-test and post-test between intervention and comparison groups. In approximately 7 months, students in the supplementary programme were on average able to gain proficiency in 7.5 additional elements of the curriculum, markedly above an average of 1.7 for the comparison group.

An ANOVA single-factor test with a *p*-value of 0.01 indicated a statistical difference across different mother tongues. However, students with Tokodede as their mother tongue showed greater progress than those with Tetum. Since the language groups were separated by tutors and locality, it is more likely that other factors contributed to the performance gap, rather than the mother tongue itself. Given that most students in this programme learnt Tetum from a young age,

regardless of their mother tongue, this variable seems less significant compared to other factors. Future studies could explore the impact of Tetum and Portuguese instruction more directly.

Few parents or students commented about the language of instruction used in the programme. However, one parent expressed that a common initial hope of students is to learn English in afterschool programmes. However, in practise, this programme focuses instead on mathematics. This discrepancy "demotivates the students' will" to participate and students "must have a discipline of language [English]" to maintain their motivation. This parent appreciated the importance of mathematics, but suggested that English should be the channel of its acquisition. This way, students could learn both disciplines considering they already "daily speak Tetum" at home. This is reminiscent of (Setati, 2008) findings about the political (social and economic) value of learning mathematics in English in South Africa as opposed to the epistemological access granted by learning in a mother tongue. In response to this, we refer to a World Bank policy approach paper, titled *Loud and Clear* (Hamam, 2021), which states, "requiring teachers to provide instruction in languages that neither they nor the students speak is a common practise despite the evidence that 90 percent or more of students may fail to acquire foundational skills such as basic literacy and numeracy in schools that implement these policies" (p. 8). We therefore maintain our stance on using Tetum for mathematics instruction.

Students' perceptions and attitudes towards using worksheets as the main instrument for learning mathematics was gauged through surveys. A total of 69 out of 81 respondents stated that they like using worksheets *very much*. Only one student stated that they did not like using worksheets. Seven others stated that they like it *a little*. This echoes a similar study in Türkiye in which students expressed satisfaction and engagement with the use of worksheets (Atasoy & Akdeniz, 2006 as referenced by Celik et al., 2022). Homework is distributed using worksheets and students have choice in its completion. This gives another picture of student affinity toward worksheets. In a question on regularity of homework, 44 of 81 students mentioned that they carry out their homework *regularly*. Then, 34 others stated they do so less often. Approximately half of the students would prefer to engage in other activities rather than completing worksheets when given the choice to do so independently at home. When asked to compare the use of worksheets in learning to a teacher-centred approach on the board, responses were not determinative. A third of students preferred teachers giving instruction on the board and another third preferred using worksheets. A handful of students preferred both methods equally. When asked which method was more helpful in learning mathematics, responses matched the former question on preference. This means that students who preferred either method generally found that method to be more effective in their learning. In written responses, students who preferred using worksheets stated that worksheets give visual input and they can take worksheets home for future reference. Worksheets also enable tutors to explain the concepts one-on-one which some students preferred. One student also noted that use of worksheets allows her to try again if she makes a mistake. Proponents of instruction at the board stated that this gives teachers a chance to explain to the whole class, to call students to the front, and if students make a mistake, it is easy to erase the board.

Whilst worksheets were foundational in teaching content, field visits affirmed that they needed supplementation in some cases. It was important to teach rotation of shapes through rotating a pencil, or to teach patterns through simple beats. Students were not able to easily grasp that 3D shapes have vertices hidden from view on a printout until actual shapes were made using cut-up foam of a sandal and toothpicks. Counting money using printed coins on a single sheet was much harder than doing so by arranging cutouts. Teaching the Earth's rotation using pen and paper was not as effective as using two balls and the light of a mobile phone. In short, employing multiple senses through a multisensory approach (Georgieva, 2024) needed to supplement the worksheets. As tutors gain experience, their repertoire of hands-on activities to complement worksheets expands.

An overview of these results seems to suggest that worksheets have a place in tutoring but must not be the sole means of instruction. When ideas need to be explained to multiple students, instruction at the board is an effective strategy. When a concept is difficult to understand, a multisensory approach is more suitable. From a sociocultural lens, learning takes place not due to worksheets, but due to the opportunity that worksheets provide: to have an ongoing interaction among the tutor and students, in an accessible language with concepts connected to the participants' social context where applicable, for example, by using Timorese coins. In this light, worksheets act as a tool to foster interaction at a suitable cognitive level for each student.

We compare these results with SEA-PLM (UNICEF & SEAMEO, 2020), in which Lao PDR was the lowest performing country. Whilst 67% of students in Lao PDR demonstrated an understanding of place values and 43% were able to apply units of measurements, only 39% of students in Timor-Leste ($n = 390$) showed proficiency in place values and only 3% were able to identify appropriate units for both weight and distance. This comparison is tempered by the observation that there are differences in the instruments, test criteria, and marking schemes. Further, the Timorese students were on average slightly older than those in Lao PDR who were in grade 5. Nonetheless, we can make some relatable statements without intending to draw a grim picture of Timor-Leste, but to alert that more is needed. This is to encourage educators to teach a wider array than to focus exclusively on arithmetic and counting and to highlight the need for remediation.

Conclusion

Late primary and middle-school students in Timor-Leste show low proficiency in most of the mathematics curriculum strands. Most students tested could not read time on an analogue clock, count money printed on paper, or complete patterns involving rotation, among many other competencies tested. A decade on, we echo the "worrisome" sentiments of the 2011 early grade mathematics assessment report (Silva et al., p. 6) for middle school students. Nonetheless, we adopt an optimistic outlook when considering remediation programmes.

The results of the tuition programme introduced in this paper suggest that individualised remedial tutoring using worksheets in the Tetum language is effective in

advancing academic gains in the context of Timor-Leste, particularly when incorporating visual aids. From survey responses, it is fair to conclude that students are content with using worksheets and value their role alongside traditional instruction. Survey results also suggest that tutor interaction is most important, whether one-on-one or in groups and individualised worksheets often tailer such explanations to student needs. Viewed from the perspective of sociocultural theory, academic achievement in the results may be explained by the dialogic interaction between the tutor and students. Effective outcomes may be achieved when the language of instruction is one with which students are familiar and students are assisted individually on tailored tasks supported through multisensory activities. The tuition programme has the potential to improve by refining its worksheets through field testing, maintaining its student cohort for longer periods, and enhancing the training of its tutors. Its scalability relies on increased funding (primarily for tutor wages) and streamlining the tutor training process.

The results of this research have additional implications for how school teachers teach mathematics. It is imperative that foundational skills and understanding are addressed prior to introducing new content, with particular attention needed for geometry, quantities and measurements, and organisation and data processing. Schools may request the assistance of older, competent students as volunteers to work with junior students in small groups on specific knowledge gaps through Tetum material and instruction. This paper demonstrates that improvement can come from relatively low-cost grassroot approaches.

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Declarations

Ethical approval This research was approved by the Human Research Ethics Committee of Charles Darwin University to be in accordance with the National Statement on Ethical Conduct in Human Research. The research was also approved by the Ethics Committee of the National Institute of Science and Technology in Timor-Leste as well as local chiefs and school principals. Parents and participating students also gave their written consent to be involved.

Competing interests This research was also part of the first author's PhD studies.

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