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ENHANCING EARLY MATHEMATICS EDUCATION FOR FUTURE DEVELOPMENT IN SOUTHWEST SUMBA

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Southwest Sumba Regency [Kabupaten Sumba Barat Daya] faces considerable challenges in early mathematics education and broader educational infrastructure. Addressing these issues requires targeted interventions to enhance teacher and student quality so to improve literacy and numeracy. This presentation introduces a pioneering project focused on the development of early mathematical education at a Teacher College in Weetebula, Southwest Sumba. One core concern is to support the College in the development and expansion of its early childhood education area, both in teaching and research. The project operates as a modular system, wherein students, including prospective faculty members of the Teacher College, acquire mathematical didactic knowledge through collaborative engagement. These acquired insights are then put into practice within primary schools, preschools, and domestic environments. The innovative approach outlined herein seeks to not only address the existing educational challenges but also foster a sustainable foundation for improved mathematics education in Southwest Sumba, thus paving the way for enhanced learning outcomes.

INTRODUCTION

Sumba is an island, approximately 150 kilometers long and 40 kilometers wide, located in the East Nusa Tenggara [Nusa Tenggara Timur] province in eastern Indonesia. Among its four regencies, the two western ones, namely West Sumba and Southwest Sumba, are relatively less developed. In the broader Indonesian context, these areas are categorized as rural and remote, characterized by underserved (educational) infrastructure and limited access to resources.

Early Childhood Education Challenges

A significant concern in East Nusa Tenggara is the restricted access to early childhood education for children under the age of six [PAUD: Pendidikan Anak Usia Dini]. This limitation is attributed to a shortage of teachers, inadequate facilities, insufficient infrastructure for preschools, and a lack of community awareness regarding the crucial role of early childhood education. As a result, access to preschools in this region is notably deficient (INOVASI, 2019, p. 17).

Educational Landscape in Southwest Sumba

The situation in Southwest Sumba presents distinctive challenges. Data from the Indonesian Ministry of Education and Culture (MoEC), as documented in INOVASI (2019, p. 18ff), reveals that during the years 2016/2017, only 28.95% of children in Southwest Sumba attended a preschool. Furthermore, the qualifications of teachers were suboptimal, with 55.50% possessing training solely below a 4-year diploma. A staggering 84.60% of schools lacked accreditation, and equipment in many schools remained inadequate. The World Bank's assessment in 2016 estimated that a mere 5% of primary school teachers in Indonesia possessed the requisite teaching skills to enhance students' learning outcomes (UNICEF & UNESCO, 2021, p. 46).

Prioritizing Interventions for Educational Enhancement

In addressing these challenges, the following three priority interventions have been identified to enhance education quality in Southwest Sumba, as outlined in INOVASI (2019, p. 34):

1. Teachers: [a] Teacher distribution and fulfil the demand for PNS teachers
[PNS: Pegawai negeri Sipil / civil servants]; [b] Improving teachers' qualifications and quality;

2. Improve literacy and numeracy;

3. Fulfil the 20% ABPD allocation for education
[APBD: anggaran pendapatan dan belanja daerah / local government budget funds]".

Electrification Progress & Access to Technology

A study conducted by Wen et al. (2022, p. 5) reveals that the percentage of households in Southwest Sumba with access to the "Main-grid connection" for electricity increased from 24.6% in the years 1982-2000 to 46.2% in the years 2011-2019. However, it is essential to note that while electrification rates have shown improvement, the overall quality of electricity services remains relatively low (ibid, p. 10).
Regarding "households' access to technology," this study highlights that while 82% of the poorest households possess televisions and mobile phones/smartphones, these devices lack internet access. In contrast, only 1% of households have internet connectivity (UNICEF & UNESCO, 2021, p. 42).

Geographical Disparities and Educational Inequality

UNICEF & UNESCO's study (2021, p. 10) underscores the challenges faced by children in marginalized regions, including Papua, East Nusa Tenggara, and Sulawesi. The study also highlights a significant issue within the Indonesian educational landscape: geographical inequality, particularly concerning the quality of education. This disparity becomes evident when comparing the main island Java with other inhabited Indonesian islands. The Competency Assessment Indonesian Students (AKSI) results demonstrate the stark contrast, with eastern Indonesian islands such as Sulawesi, Papua, the Maluku Islands, and the Nusa Tenggara Islands exhibiting notable disparities compared to DKI Jakarta and DI Yogyakarta in terms of AKSI scores [DKI: Daerah Khusus Ibukota / Special Capital Region, DI: Daerah Istimewa /Special Region]. Although the AKSI score itself does not determine graduation or class promotion, it provides valuable insights into literacy skills and elementary student numeracy (UNICEF & UNESCO, 2021, p. 26).

PROJECT "PAUD AT WEETEBULA"

The project is being carried out in the Weetebula area, with most of the activities taking place at the Sekolah Tinggi Keguruan dan Ilmu Pendidikan (STKIP; Teacher Training and Pedagogy College). Thanks to its own significant efforts, STKIP was able to evolve into the Universitas Katolik Weetebula.

Under the guidance of Sister Mathilde Franke and Inge Schwank, 27 students, divided into 3 small groups, initially received 5 weeks of instruction, consisting of two sessions lasting 120 minutes each, on fundamental concepts of mathematics didactics, mathematical-logical thinking, and logic blocks. Subsequently, they conducted practical training as case studies in pairs, working with a student each.

Following this, the students continued with 7 weeks of instruction in the same 3 small groups, with one session per week lasting 150 minutes. Topics covered included basic numerical concepts, the calculation spiral staircase (Schwank & Schwank 2015, p. 779ff), acquiring numerical writing skills, and mathematical problem-solving (Schwank 2016, 2020; Fauzan et al. 2020). Two future educators in the field of early mathematical education at the Teacher College were involved in each session. After each teaching session, they engaged in reflection discussions. Furthermore, they were actively involved in a kindergarten where they applied the learned concepts of logic blocks.

All activities, encompassing teaching sessions, reflective discussions, case studies, and kindergarten experiences, were meticulously captured through video recordings. In select instances, photographic documentation was also employed. Additionally, scanned copies of written assignments have been amassed, with the majority having undergone thorough assessment. Collectively, these resources constitute a wealth of valuable material for academic utilization at the Universitas Katolik. For a first impression, please refer to Figures 1 and 2.

Figure 1: Learning at the Teacher's College.
Left: Teaching of students in the presence of two future lecturers (front left)
Right: Preparation for the numeral writing course: The correct sequence of moving the coins, each of which is labeled with an icon – crown, dog's face, circle – on the wooden numbers is supported by the saying "The king hops with his dog over the balls".

Figure 2: Playing with logic blocks for Kindergarten Children.
Left: A future lecturer is gathering practical experience and tries himself out.
Right: Case study by a female student on logic blocks in a domestic environment.

It is worth noting that the students themselves had minimal formal education in the traditional sense. They learned writing, letters, and numerical symbols through tracing and copying, rather than through a formal writing course. Consequently, the numerical writing course played a significant role. Emphasis was also placed on understanding children's mathematical problem-solving abilities, including a focus on primary school mathematical content (Schwank, 2020).

To conduct their individual studies, the students were introduced to the use of video cameras, which took some time due to their lack of experience with electrical/technical devices. They successfully carried out their case studies independently, primarily in domestic settings—mostly within the families where they resided as students and contributed to household tasks.

With this project, it is also intended to contribute to the important topics under discussion, as elaborated by Vithal et al (2023) in the context of their extensive review on 'Equity in Mathematics Education,' particularly focusing on 'Equity-focused practices, pedagogies, and teacher education', as well as 'Mathematics curricula, content, access, and pathways'.

Key sequences from the created videos are extracted using a headline guide, then extensively analyzed using category systems and prepared for subsequent educational use. The evaluation is still ongoing, planned visits could not be carried out due to the COVID-19 pandemic but are scheduled to resume in summer 2024.

Thanks to the wonderful assistance of Sister Mathilde Franke, the teaching could be conducted in Indonesian as she handled the translation between German and Indonesian.

The significant success of the project lies in demonstrating how students and future educators can acquire mathematical didactic knowledge and effectively apply it, even in those challenging circumstances. The small group size, the participants' strong enthusiasm, and their unwavering dedication have contributed significantly to this achievement.

EARLY MATHEMATICS AND COMPUTER SCIENCE EDUCATION

Early education encompasses a wide range of subjects, necessitating integrated approaches. Incorporating basic concepts of computer science into early mathematical education is advisable, as it provides children with limited access to education sustainable opportunities for future equitable participation in the digital society. Continuing our previous collaborations, a multi-week online course was conducted with lecturers from Universitas Katolik Weetebula, focusing on establishing foundational knowledge about early computer science education in the context of early mathematics education. Through these expanded activities, a concerted effort is made to support the overarching goals, as articulated, for example, by UNESCO IITE et al. (2022), in harnessing and promoting the potential of digital innovations.

Since Papert (1980), there have been various considerations on how to introduce children to specific thought processes of computer science. One approach is to utilize Dynamic Labyrinths (Börger 2022, Cohors-Fresenborg, 1987). This concept, rooted in mathematical logic and basic research, exemplifies automata theory. Dynamic Labyrinths are deceptively simple, comprising only a few basic elements, yet they are computationally universal, meaning a Dynamic Labyrinth can theoretically be built to compute any computable function. Thus, Dynamic Labyrinths can be applied from kindergarten through primary and secondary schools to universities, underscoring their importance as a cornerstone of fundamental computer science education.

Mathematical definitions are omitted here. Instead, the real construction set of Dynamic Layrinths and its digital implementation through an app are utilized (see Figure 3). The tangible building blocks provide an enactive representation form for organizing processes and procedures, illustrations and drawings of these an iconic representation form, and the app, a virtual-enactive representation form. 3D models for printing the building blocks with a 3D printer are available. The building blocks themselves are language-free, facilitating their use. The app can be used largely without language barriers; its interface exists in multiple languages, so far in English, Indonesian, Chinese, Persian, and German (https://mathedidaktik.uni-koeln.de/dynamic-labyrinths).

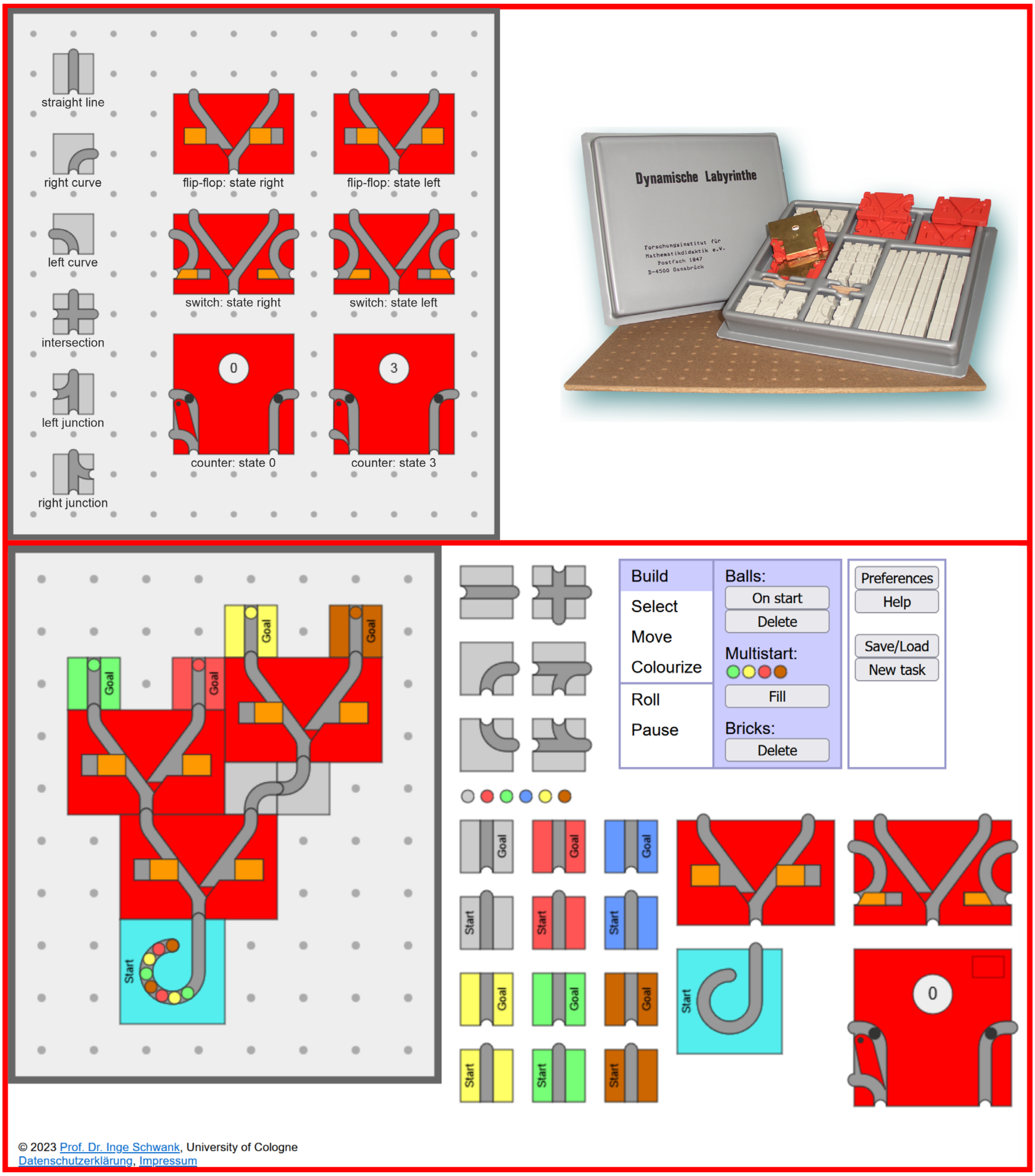

Figure 3: Dynamic Labyrinths.
Top left: the 6 types of path elements (gray stones) and 3 types of controllers (red blocks) – placed on a virtual pegboard. Top right: The Dynamic Labyrinths construction set with pegboard for placing the elements. Bottom: The DL app for building Dynamic Labyrinths virtuall-enactively.

Engaging in the purposeful structuring of workflows and processes and thus in organized actions in space and time is challenging, requiring adherence to rules, exploration of possibilities, and creative problem-solving. A starting point is to design paths. For this purpose, there are the path elements of the Dynamic Labyrinths. In total, there are six types: Straight, Curve (left/right), Intersection (left/right), and Crossroad. Additionally, there are three types of controller elements that introduce dynamism to the Labyrinths, allowing future travel or repeated traversal to be contingent on conditions: Flip-Flop, Switch, and Counter. By incorporating Intersection and Switch, it's theoretically possible to construct all finite automata, while adding the Counter enables the construction of Dynamic Mazes for all computable functions. In Figure 3, bottom left, three flip-flops are used to sort balls traveling through the Dynamic Labyrinth in the repeating color sequence 'green, yellow, red, brown' according to their colors, with each ball reaching its destination based on its color. As the flip-flops switch positions with each cycle (right free → left free, or left free → right free), the passage of each ball triggers the release of an appropriate path for the next ball.

Number construction sense

The development of arithmetic thinking can significantly benefit from specific aspects of computational thinking. Given the increasing societal significance of computer science, it's crucial to foster synergistic effects to promote the development of mathematical-computational thinking in students. This includes promoting an understanding of numerical relationships through processes inherent to natural numbers, fundamentally contributing to the development of numerical construction sense in children (Schwank & Schwank, 2015, p. 775f). Figure 4 illustrates an example of handling natural numbers following the approach: "Understanding of numerical relationships through processes / Numbers from a process management perspective.".

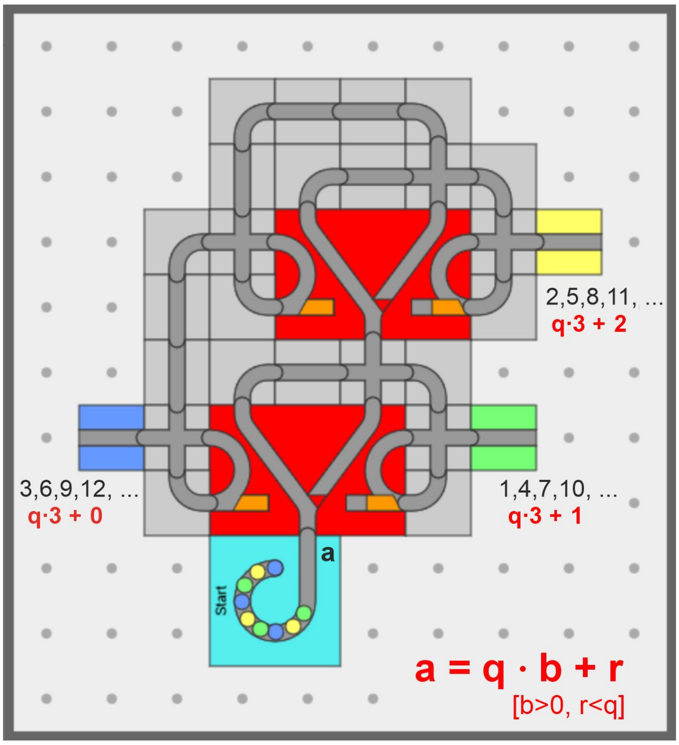

Figure 4: Constructive-dynamic perspective on natural numbers using the example of their construction as specific multiples.

Every natural number can be constructed or deconstructed as the multiple of another natural number plus a certain remainder: Each number **a** embodies a construction, namely being the largest possible multiple **q** of another number **b** plus a specific remainder **r**. In the example provided in Figure 4, numbers **a** are processed in terms of forming multiples of **b=3** to reach the corresponding target regarding the remainder **r**.

A good orientation to considerations regarding approaches to mathematical ideas, especially whole numbers, in primary school education is provided, among others, by Hodgson (2018). The easily accessible connections between mathematical and computational early education are still largely unexplored research territory. Children from disadvantaged backgrounds, for whatever reasons, must always be considered in terms of their specific needs due to the circumstances of their environments.

FINAL REMARK

Mathematical-computational thinking presupposes basic cognitive processes. The British psychologist Charles Edward Spearman (1904) was already devoted to the study of logical thinking (as a form of fluid intelligence). The now widespread use of so-called figural matrix tasks traces back to him. Little known is the fact that (among others) two different approaches to problem solving are possible: a predicative-logical approach and a functional-logical approach (Schwank & Schwank, 2015, p. 773f). Remarkably, individuals may differ in their preference for and aptitude in each of these approaches. In our context, it is significant that the ability for functional-logical thinking greatly facilitates the development of arithmetic thinking and overall comprehension of actions, processes, and dynamics. Therefore, to promote process-based mathematical-computational thinking, it is crucial to pay great attention to fostering functional-logical thinking.

Figure 5 depicts an example of a figural matrix task. Remarkably, it was developed by the first author with a clear view of the construction sequence of the figures, guided by dynamic, interwoven processes (functional-logical). It wasn't until later that some of her colleagues brought to her attention the inherent structure, governed by invariants of static features (predicative-logical). It is left to the reader to devise a coherent solution figure, in one way or another, or perhaps even in multiple ways.

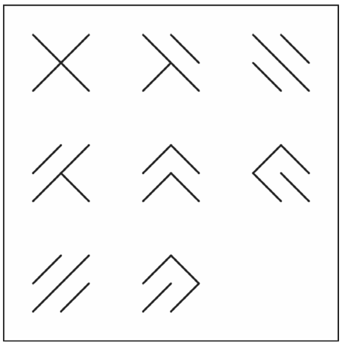

Figure 5: Which figure fits well in the empty space
at the bottom right in the shown figural matrix problem? (Schwank 2000)

We see it as our mission, together with the lecturers and students of the Sumbanese universities, taking into account the local conditions but with a firm focus on the needs and necessities of future generations, to further develop mathematical and computational education for children in primary school with effective preparations in kindergarten and to establish it widely for the benefit of all.

In a way, a fast lane is being taken in that Sumbanese adults, who themselves have received little or no formal education, are now paving the way for children for their lives as equal professionals in the global world of tomorrow.

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