Framework Development for Transdisciplinary Knowledge Management in Minecraft-based Mathematics Learning

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Abstract: *This paper develops and applies a Transdisciplinary Knowledge Management (TKM) framework for technology-enhanced mathematics learning in post-pandemic settings. Using a mixed-methods design (literature review, SWOT, and a validated online survey of 50 teacher trainees), we examine how access to equipment and supportive study environments relate to learners' satisfaction with digital collaboration and to the effective orchestration of digital tools. We then demonstrate the framework through a detailed classroom-adjacent case that integrates Minecraft: Education Edition with Padlet, Telegram, and YouTube. In the case, a Malaysian primary school learner models a local cultural event (the Penang Chingay parade) inside Minecraft, engaging explicitly with geometry (3-D solids, symmetry, spatial coordinates), measurement and scale (block-to-meter mappings, ratio and proportion), early algebraic thinking (repeating patterns, even/odd structure, step-wise rules), and mathematical modeling (assumptions, simplifications, iterative validation). Results from the survey indicate that equipment access and supportive environments are strong predictors of overall learning satisfaction, reinforcing the need to pair pedagogy with robust digital infrastructure. The case study shows how game-based environments can make abstract ideas tangible while sustaining motivation and cultural relevance, and how the TKM framework helps facilitators of transdisciplinary learning to manage knowledge flows across devices and platforms. We contribute: (i) a theoretically grounded, tool-agnostic framework for coordinating technology in mathematics-rich STEAM projects; (ii) concrete math tasks and design rationales that leverage Minecraft for modeling, measurement, and structure; and (iii) evidence that coordinated KM practices can improve learner experience and mathematical engagement in technology-mediated contexts.*

1. Introduction

The COVID-19 pandemic significantly accelerated the adoption of digital Science, Technology, Engineering, Arts, and Mathematics (STEAM) education in Malaysia. The digital transformation in education created both new opportunities and exposed persistent challenges, particularly in supporting transdisciplinary learning [1]. Underprivileged learners and those in remote areas continue to experience substantial barriers, including limited technical support and inadequate infrastructure [2]. This paper presents a post-pandemic case study from an ongoing research initiative that implements a transdisciplinary STEAM curriculum in Malaysia. The project develops a framework for transdisciplinary Knowledge Management (KM) based on digital platforms and tools to enhance project-based learning (PBL) in Malaysian educational settings.

A growing body of literature supports the idea that the use of multiple digital devices enables seamless learning, allowing students to transition fluidly between different contexts and environments. This is facilitated by cloud-based services, internet connectivity, and context-aware software [3], [4]. Learners may use devices independently or combine mobile technologies with fixed digital systems to support their learning processes—either sequentially or simultaneously—across various locations, including classrooms, informal out-of-school settings, and co-curricular activities. At the same time, many students and institutions encounter significant obstacles in adapting to the flexibility of technology-enhanced learning, revealing persistent gaps in digital infrastructure and in the competencies of both educators and learners.

In this regard, transdisciplinary approaches to mathematics education are particularly affected. The exploration and understanding of abstract concepts—such as spatial reasoning, proportionality, and algebraic structures—become more approachable to young learners when reframed within transdisciplinary contexts and supported by interactive and visual tools. Digital platforms, especially game-based environments, provide concrete opportunities to transform mathematical abstractions into complex, tangible, and engaging learning experiences.

The Minecraft: Education Edition (MEE) has emerged as a powerful platform for creative and collaborative PBL, offering immersive possibilities for transdisciplinary mathematics learning and broader STEAM integration (see [5] and [6]). While many reports discuss digital transformation and online education challenges in general, much of this literature remains disconnected from subject-specific teaching and learning, particularly mathematics in transdisciplinary contexts. This gap underscores the need for case-based evidence showing how cohesive transdisciplinary teaching frameworks can leverage digital KM platforms—using tools such as MEE, Padlet, Telegram, and YouTube—to enable effective project-based learning.

2. Theoretical Background

Our theoretical framework integrates the Seamless Learning Framework (SLF) and the Multi-Device Learning Framework (MDLF), both of which emphasize the importance of continuity in learning across digital and physical contexts [3]. These are complemented by the Technology Acceptance Model (TAM), which helps explain how learners and educators adopt and incorporate digital tools within project-based and transdisciplinary pedagogical practices [7].

3. Methodology

The rationale for this study rests on two key considerations. First, the pandemic highlighted persistent inequalities in access to quality digital education, particularly for underprivileged learners, raising urgent questions about how to align digital education practices with the United Nations Sustainable Development Goals (SDGs). Second, the complexity of transdisciplinary education demands validated tools and frameworks that can guide and evaluate curriculum development within digital Knowledge Management (KM) platforms. Based on these considerations, this study is guided by the following research questions:

- RQ1a: What lessons from the pandemic can inform the design of inclusive and high-quality digital education that supports the UN's SDGs?
- RQ1b: What insights can validate instruments for monitoring and evaluating curriculum studies provide when applied within KM platforms?

- RQ2a: How can we define and operate the key concepts of KM and transdisciplinary education in the context of Technology-Enhanced Learning (TEL)?
- RQ2b: How can a KM framework for TEL be systematically developed through SWOT analysis and Exemplary-Case Analysis (ECA), and how can this framework be illustrated through practical examples?

A mixed-methods research design was employed in this study, integrating both qualitative and quantitative approaches to comprehensively address our research questions. This methodological pluralism enables a robust exploration of the challenges and opportunities that emerged during the pandemic regarding digital education and its alignment with Sustainable Development Goal 4 (SDG4) for quality education [11].

4. Results and Discussion

Qualitative Analysis. The qualitative component aimed to answer RQ1a and RQ2a–b. To address these questions, a thorough literature review was conducted, identifying critical insights from various educational settings forced to adapt during the COVID-19 pandemic. For example, the SWOT analysis method has been employed in several contexts to evaluate the strengths, weaknesses, opportunities, and threats associated with digital education frameworks ([12] and [13] and [14]), laying the groundwork for our analysis of similar dynamics. A SWOT analysis was particularly effective in discerning the internal and external factors influencing the implementation of KM-supported transdisciplinary learning environments [15]. Concurrently, we conducted multiple-case analyses, referred to as Exemplary-Case Analysis, leveraging illustrative screenshots from digital tools such as Telegram, YouTube, and Padlet. These illustrated how community engagement and resource sharing were fostered even in remote learning contexts, thus providing useful exemplars for our proposed framework.

Quantitative Analysis (RQ1b). For the quantitative aspect of our study (RQ1b), we collected survey data using a revised College Students' Remote Online Class Satisfaction (CSROCS) instrument, which was deployed online via Wenjuanxing to a sample of 53 university teacher trainees in China during the pandemic. The CSROCS instrument's constructions, previously validated through Exploratory Factor Analysis (EFA), encompass three key dimensions: internal experience (IE), external experience (EE), and learning equipment guarantee (LEG).

To explore the relationships among these constructs, we performed a Current Situation Analysis (CSA), which revealed insights into the participants' satisfaction with remote instruction. Furthermore, a Pearson Correlation Analysis (PCA) was conducted to examine the correlations among the IE, EE, and LEG dimensions, as shown in Table 1. The analysis yielded significant positive correlations ($r = 0.676, 0.311, 0.889$, respectively), indicating that greater access to learning equipment correlates positively with both internal and external learning experiences. These findings resonate with existing literature that emphasizes the importance of technological access in enhancing remote education experiences ([14] and [16]).

Factor	Dimension's Name	Items	N	Least value	Crest Value	Average Value	Standard Error
1	Distance learning of students' Internal Experience (IE)	Q1-Q8	50	1	3.63	1.86	0.8492
2	Distance learning of students' External Experience (IE)	Q9-Q13	50	1	3	2.06	0.6221
3	Learning Equipment Guarantee (LEG) for Distance Learning (DL) students	Q14-Q16	50	1	3	1.67	0.6023

Table 1: Descriptive Statistics of Current Situation Analysis (CSA)

Literature-defined Components (RQ2a). Our qualitative review established crucial baseline definitions pertinent to the frameworks of KM and transdisciplinary education, both of which have emerged as vital components in supporting effective educational practices during and after the COVID-19 pandemic. Knowledge Management (KM) refers to the processes involved in acquiring, storing, distributing, and effectively utilizing knowledge within educational contexts [8]. Modern KM platforms – accessible via computers, tablets, and smartphones – enable seamless knowledge flow and collaboration among stakeholders in digital education. Transdisciplinary education is an approach that transcends disciplinary boundaries to collaboratively address complex real-world problems [9]. This approach is particularly relevant in STEAM curricula, where mathematics not only supports content-specific learning but also serves as a bridge for interpreting data, modeling systems, and validating creative solutions across disciplines [10].

Quantitative Findings (RQ1b). The quantitative aspects of our study revealed notable trends through the analysis of the College Students' Remote Online Class Satisfaction (CSROCS) survey results. The Current Situation Analysis (CSA) indicated a general dissatisfaction with the e-learning models employed during the pandemic. Specifically, the Pearson Correlation Analysis (PCA) demonstrated significant positive correlations among the constructs measured: students' learning satisfaction was positively correlated with equipment availability (Learning Equipment Guarantee – LEG), external experience (EE), and internal experience (IE), with correlation values of $r = 0.676$, $r = 0.311$, and $r = 0.889$, respectively, as summarized in Table 2.

This data illustrates that access to devices and platforms (LEG) is integral to enhancing learning experiences, further supported by literature indicating that reliable technical support is important for improving students' motivation and understanding [17]. Students who accessed functional technology and engaging external learning contexts reported higher satisfaction in their remote learning experiences.

Dimension	1 LEG	2 EE	3 IE	4 Overall satisfactions
1 Learning Equipment Guarantee (LEG)	1			
2 External Experience (EE)	0.054	1		
3 Internal Experience (IE)	.522**	-0.102	1	
4 Overall Satisfaction	.676**	.311*	.889**	1

**At level 0.01 (two tails), with a significant correlation *At 0.05 (two tails)

Table 2: Pearson Correlation Analysis (PCA)

To further examine the predictive effects of the three key variables – internal experience (IE), external experience (EE), and learning equipment guarantee (LEG) – a linear regression analysis (LGA) was conducted. The regression model was statistically significant ($F = 2257.918$, $p < .001$) with an excellent adjusted R^2 of 0.993, indicating that 99.3% of the variance in overall learning satisfaction could be explained by these predictors. Among them, IE had the strongest effect ($\beta = 0.806$), followed by EE ($\beta = 0.380$) and LEG ($\beta = 0.234$). These results, as presented in Table 3, confirm that all three factors positively and significantly influence students' satisfaction with distance learning.

	Unstandardized coefficients	**Standardization coefficient**	**T**	**P**	**VIF**
(constant)	0.033		1.21	0.233	
Distance learning (DL) of students' Internal Experience(IE)	0.479	0.806	56.1	0	1.407
Distance learning of students' External Experience (EE)	0.308	0.38	30.98	0	1.027
Learning Equipment Guarantee for DL students	0.196	0.234	16.36	0	1.397
After the adjustment of R			0.993		
F			2257.918		
P			.001		
Dependent variable: overall learning satisfaction					

Table 3: Descriptive Statistics of Current Situation Analysis (LGA)

Integration with Game-Based Learning (GBL). Our findings reinforce existing literature regarding the effectiveness of game-based learning in STEAM education. Evaluations of game-based learning initiatives, such as Minecraft camps, have shown positive impacts on students and parents, with notable gains in knowledge acquisition, collaboration, and motivation. Game environments like Minecraft serve as dynamic learning platforms that engage students while fostering essential life skills. Literature review has emphasized that Minecraft enhances students' environmental awareness and technical acumen, further supporting the role of game-based interactions in education [18]. These studies align with our framework's emphasis on interactive, project-based STEAM learning, suggesting that integrating engaging game-based activities can effectively captivate students across varying disciplines.

5. Framework Development for Transdisciplinary Knowledge Management

The insights gleaned from both qualitative and quantitative analyses underscore the importance of applied KM strategies in education, particularly in supporting transdisciplinary learning, where mathematical reasoning, such as pattern recognition, estimation, and proportional thinking, is integrated across disciplines. The qualitative data reveal valuable lessons for educators and administrators derived from the pivot to digital learning, while the quantitative results indicate a clear link between equipment availability and learner satisfaction.

The quantitative findings offer empirical validation for our TKM framework. A strong correlation exists between Distance learning (DL), students' Internal Experience (IE), and “learning equipment guarantee (LEG), which directly informs the framework's design. Moreover, the notable influence of LEG on both IE and overall satisfaction supports the framework’s emphasis on enhancing students’ well-being by optimizing their internal experience. This finding also underscores the importance of communication and media technologies as foundational elements for ensuring adequate learning equipment support. The significance of this framework lies in its grounding in established educational theories and in principles of multi-device learning. The model is designed to provide a holistic learning environment, where students can seamlessly engage with multiple disciplines.

The TKM framework highlights various strengths inherent in digital platforms. The accessibility of tools like Telegram and Padlet fosters community building and enhances collaboration among students and educators ([19] and [20]). These platforms enable the sharing of resources, feedback, and instructional content, effectively increasing engagement and learning outcomes. They also facilitate communication between educators and students, enabling real-time support and feedback, a critical element in online learning environments. However, this framework also acknowledges the potential threats posed by the digital divide. The disparities in access to technology may lead to inequities in educational outcomes. Therefore, low-cost and widely available tools must be prioritized within the framework to ensure that all students have equitable learning opportunities.

6. Integrating Mathematics Learning with Cultural Heritage through Minecraft in a Malaysian Primary School Student’s Project: An Example of Project Outputs

To illustrate the practical application of the TKM framework, we provide a detailed introduction to one exemplary project executed using Minecraft Education Edition (MEE). This case study presents a mathematics learning project for a Malaysian first grader (age 7), supported by university students through Minecraft, Padlet, and YouTube to model a local intangible cultural heritage event, the Penang Chingay parade. This project situated math learning in a real-world cultural phenomenon and required transdisciplinary, STEAM exploration facilitated by the university students. Chingay is a traditional street parade featuring giant flag balancing, acrobatic troupe formations, and ornate floats. It was first recorded in Penang over a century ago and remains a vibrant annual event, recently nominated for UNESCO’s Intangible Cultural Heritage list. Embedding mathematics in this familiar cultural context for students aligns with calls to make math more meaningful and connected to their lives. This project provided an informal, play-oriented extension of the official curriculum, allowing the young learner to apply school-taught concepts (shapes, patterns, measurement, etc.) in a complex, creative task. We describe the project implementation and analyze how key mathematical domains – geometry, algebraic reasoning through patterns, and mathematical modeling – were developed through the child’s Minecraft construction process.

Project Setting. The Malaysian first-grade mathematics curriculum in primary school emphasizes Numbers and Operations, Measurement and Geometry (Shape and Space), Relationships and Algebra, and patterning skills in everyday contexts [21]. Embedding mathematics in a familiar cultural context aligns with long-standing calls to make mathematics more meaningful and connected to students’ lives, reflecting educational policy directions in Malaysia since the early 2000s [22]. The project was conducted as an out-of-class collaborative activity involving a 7-year-old, first-grader student from Butterworth, Penang, Malaysia, guided by two university students in their early 20s. The goal was to recreate the local Chingay procession venue and its performances inside the Minecraft game world, highlighting mathematical aspects in the design. Roles were divided among the team: the adult collaborators handled planning, resource gathering, and documentation, while the 7-year-old math learner served as a “world-builder” – executing builds in the Minecraft game world and solving emergent math problems. Notably, the child had prior Minecraft experience, enabling her to take on the spatial modeling challenges with enthusiasm. The whole project has been demonstrated in a video accessible on YouTube [26].

Site Exploration and Data Gathering: To ground the modeling in reality, the team first visited the actual parade site (a city street) and documented key landmarks via photographs and sketches. They also consulted maps and satellite images of the area. Using a built-in Minecraft Book, they compiled notes and images about the venue’s layout, sizes of buildings, and distances between parade features (e.g., the main stage, spectator stands). This preliminary study introduced the child to basic measurement and scale concepts: for example, identifying a building’s height in real terms (e.g., “five floors tall”) and deciding how many Minecraft blocks would represent that height in the model. The process involved interpreting different map scales and zoom levels – a rich geometric problem-solving exercise rarely encountered in a typical first-grade class. Examining maps at multiple scales to understand the area’s geometry gave the first steps of mathematical modeling of the location. The child learned to make mathematical approximations and decisions about what features were important to include (e.g., “How long should the parade route be in the Minecraft world relative to building sizes?”).

3D World Construction: Guided by photographs and the site data, the 7-year-old recreated the parade environment block by block. This entailed the construction of several buildings along the street and the street itself. Each build required recognizing fundamental 3D shapes (cubes, rectangular prisms, pyramids, cylinders) that composed the structure, akin to how the curriculum expects students to “name the shape of cuboid, cube, cone… and create new models using combinations of three-dimensional shapes.” For instance, a temple facade was modeled by combining rectangular prisms for walls and triangular prisms for the roof, while a fountain was approximated by a cylinder shape. The student engaged in considerable spatial reasoning – figuring out the dimensions, proportions, and placement of each part to mirror the real layout. A key mathematical challenge was scale fidelity: ensuring that if Building A is twice as tall as Building B in reality, the Minecraft versions reflected that ratio. This led the child to informal proportional reasoning (e.g., “If I made Building B 10 blocks high, Building A should be about 20 blocks”). Such scaling is a form of mathematical modeling: the child was mathematizing the real world by establishing a block-to-real-world size correspondence. The task also reinforced concepts of counting and number sense – e.g., counting out blocks for length and comparing magnitudes (“more than”, “less than”) – which are core skills for a first grader in Malaysia.

Throughout construction, the student encountered the discrete nature of the Minecraft grid. Curved or diagonal structures (such as an arched gateway or the rounded edges of a float) had to be approximated with aligned blocks. This required the child to recognize and create patterns of blocks to simulate slopes or curves, thereby exercising pattern recognition and early algorithmic thinking. For example, to build a sloping roof, the child repeated a stepwise pattern of blocks (decreasing one block in height for each step outward), discovering a linear pattern. This resonates with the curriculum’s focus on recognizing and creating patterns with shapes. The symmetry of certain designs emerged as a consideration as well: the student noticed that many cultural motifs (e.g. a Chinese pavilion roof, or the arrangement of lanterns) were symmetric, and thus she placed blocks in mirrored arrangements on either side of a center line. Identifying bilateral symmetry and maintaining equal counts on both sides gave practice in an important geometric concept (even if symmetry per se is not formally taught until later years, the child engaged with it intuitively).

Modeling Dynamic Elements: Beyond static architecture, the project developed mathematical models for the dynamic components of the Chingay parade, including floats, vehicles, and human performances. The child was challenged to build a miniature truck and trailer used in the parade to carry performers. This involved breaking down a real vehicle into basic shapes (rectangular body, circular wheels) that could be constructed with blocks, essentially a hands-on exercise in geometric abstraction. Moreover, to populate the parade, the team decided to represent the iconic "Big Banner" acrobatic performance in which performers balance a 12-meter flag. The 7-year-old built block figurines for the acrobats and a tall vertical pole for the banner. Here she had to calculate how many performers to include and how to space them. The performers in the real act stand in a symmetric formation around the banner, so the child arranged the Minecraft figures with rotational symmetry (four performers at equal intervals around the flag). She counted the avatars and adjusted positions so that distances were roughly equal – a concrete exercise in division (partitioning a circle into equal parts) and spatial proportion. The computational thinking element emerged as she scripted simple in-game behaviors: for example, using Redstone (Minecraft's circuitry) to make parade floats move along the road. Though rudimentary, this introduced the idea of step-by-step logical instructions, connected with algorithmic reasoning underlying early algebra.

Throughout these tasks, the child continuously compared her Minecraft models with reference images of the actual parade. This reflective mathematical modeling cycle – iterating between the real-world object and the virtual representation – required her to make assumptions and simplifications (e.g., choosing a uniform size for human figures, deciding which decorations on a float are essential to model and which to omit). Such decisions mirror the processes of formal mathematical modeling described in literature (identifying variables, selecting essential elements, mathematizing them, and validating the model), albeit at an age-appropriate level. Primary students can engage in non-trivial modeling when contexts are familiar and motivating. In this case, the familiar cultural narrative of the parade kept the student motivated to persevere through complex problem-solving. She was effectively doing what English (2006) calls "children's mathematical modeling of a community context" – a process that builds foundational reasoning skills even without advanced formal math.

Documentation and Presentation. To consolidate learning, the team built an "Education Center" inside the Minecraft world – essentially a virtual exhibition pavilion along the parade route. In this space, they displayed maps, photos, and explanatory signs highlighting mathematical aspects (e.g., a signboard showing the real parade route length vs. the Minecraft route length in blocks, or a gallery of block patterns used to mimic traditional batik motifs on a float). Creating this exhibit pushed the student to communicate her mathematical ideas, aligning with curriculum goals of mathematical communication and connection. She helped compose simple descriptions (with adult assistance) for concepts like "scale 1 block: 1 meter" and "even number of lanterns for symmetry". In doing so, she practiced using mathematical language in context. Finally, the entire project was recorded as a 3-minute video walkthrough of the Minecraft world (with commentary) to share with peers and teachers. In the video, the young learner proudly tours the virtual Chingay parade, explaining how she built each part and pointing out its mathematical features (counting the flag bearers, describing the shapes of floats, etc.). This presentation component further reinforced her learning by requiring reflection and articulation.

Analysis. Linking to Curriculum and Learning Outcomes: The project richly addressed geometry content expected in early primary education. In our case, the student moved beyond mere identification to hands-on construction of complex structures, deepening her understanding of the properties of shapes (faces, edges, symmetry) through application. Research has shown that engaging young children in building activities can enhance their spatial visualization and geometric reasoning skills. Jensen and Hanghøj's study of Minecraft in math class noted that students naturally use coordinate positions and spatial frames of reference while building, linking game actions to formal math concepts like grids and axes [23]. In this project, although the child did not formally use Minecraft's coordinate system, she implicitly learned the idea of a 3D grid and coordinate positions when navigating the world and placing blocks at the correct locations. The immersive and interactive nature of Minecraft served as a "micro-world" (in Papert's sense) for exploring geometric concepts in a concrete yet creative way.

Early algebraic thinking in Grade 1 often involves recognizing patterns and relations. The students' need to replicate patterns (for ornamentation and for structural design, like repeated fence posts or rhythmic spacing of parade participants) provided a meaningful context for patterning skills. Rather than completing worksheets of patterns, she was creating them in the service of a larger design. This resonates with the concept of model-eliciting activities in mathematics education, where students derive mathematical structures (such as patterns or formulas) from realistic situations. Here, the situation was designing a parade layout; the patterns emerged naturally (e.g., alternating red and white blocks to mimic the Malaysian flag on a float). She also confronted the concept of even and odd numbers when striving for symmetrical builds. For example, she discovered that making a gateway symmetrical required an even number of blocks in its span (an observation commonly reported by Minecraft-playing students learning parity and symmetry). Such experiences link to algebraic reasoning by highlighting structural constraints and simple relationships (even numbers yield symmetry, odd numbers yield a center point, etc.). These are precursors to more formal algebraic concepts and are achieved in a playful, self-motivated manner.

Most significantly, this project engaged a young student in genuine mathematical modeling – a practice usually reserved for older students. In line with findings by English (2006) [24], primary pupils can participate in modeling when tasks are developmentally appropriate and tied to tangible contexts. The 7-year-old in this case identified important quantitative attributes of a cultural phenomenon (sizes of structures, counts of performers, timing, and spacing in a procession), mapped those into a simplified representation, and iteratively refined her model. She made approximations (e.g., using a 1-meter block to stand for a person ~1.5 meters tall) and assumptions (e.g., fixing all human figures to the same size for simplicity) – key steps in the modeling cycle. With guidance, she also interpreted and reflected on the accuracy of her models, such as checking if the street in Minecraft "felt" as crowded as in real life when populated with her built spectators. This reflection mimics the validation step of modeling (comparing model outcomes with reality and adjusting). Educational research suggests that even at early ages, modeling activities build mathematical reasoning and communication skills, as children justify their choices and explain their thinking. We observed the students' confidence and mathematical vocabulary grow as a result of this project. Initially, she referred only to "big" and "small" or "a lot of blocks"; by the end, she comfortably used terms like "longer", "taller", "half", "corner", and "pattern", demonstrating an internalization of concepts through practice. Crucially, the project also fostered 21st-century skills like creativity, collaboration, and cultural awareness. These are emphasized in the national curriculum framework as essential outcomes. By integrating cultural heritage, the activity strengthened the students' sense of identity and appreciation for local traditions, illustrating the often-neglected link between mathematical thinking and cultural context. This echoes the ethnomathematical perspective that mathematical ideas are embedded in cultural practices and can be a rich resource for teaching (e.g., exploring geometry in traditional crafts or performances).

Another notable outcome was the students' heightened engagement and disposition toward mathematics. Working in Minecraft turned abstract concepts into something tangible and fun. This aligns with broader findings that game-based learning environments like Minecraft can increase students' enjoyment and confidence in math. The Irish nationwide study by Slattery et al. (2023) reported that primary students found Minecraft Education "easy to use, useful, and enjoyable" for learning, citing themes of immersion, collaboration, and agency [25]. We observed similar effects: the 7-year-old remained remarkably focused during multi-hour building sessions, treating each mathematical problem as a creative challenge rather than a chore. She also exercised agency in decision-making – for example, devising her own method to evenly distribute lanterns along the parade route by placing one every 5 blocks and adjusting at the end. Such experiences likely contribute to a growth mindset in mathematics. By solving problems in a self-directed way, she began to see herself as a capable "mathematical thinker," not just a young student following a textbook. In interviews after the project, the child described math as "something that helps me build things" – a powerful shift from viewing math as only arithmetic drills.

Lessons learnt. This case study illustrates several broader implications: (1) Young learners benefit from context-driven math tasks that allow them to bridge school mathematics with their lived world, reinforcing the curriculum's push for real-world connections. (2) Culturally relevant contexts (like local traditions) can powerfully motivate children and give mathematics a meaningful narrative, an approach resonant with both ethnomathematics and modern STEM education trends. (3) Sandbox games such as Minecraft provide an immersive environment for phenomenon-based learning, where students simultaneously cultivate creativity, collaboration, and computational thinking alongside math content knowledge. While this was a single-case exploration, it hints at the potential impact of similar projects. Future work could document more of these cases and assess learning outcomes more formally – for example, comparing students' understanding of shape and measurement before and after a Minecraft modeling project. The insights gleaned from both qualitative and quantitative analyses underscore the importance of applied KM strategies in education, particularly in supporting transdisciplinary learning, where mathematical reasoning, such as pattern recognition, estimation, and proportional thinking, is integrated across disciplines. The qualitative data reveal valuable lessons for educators and administrators derived from the pivot to digital learning, while the quantitative results indicate a clear link between equipment availability and learner satisfaction.

7. Conclusion and Future Work

This study provided empirical insights into the post-pandemic technology-enhanced learning and informed the development of the TKM framework, which integrates game-based learning (Minecraft), knowledge management (KM) tools, and well-being considerations to support inclusive, future-oriented STEAM education. Quantitative findings underscored the significance of students' internal and external learning experiences, along with access to learning equipment (LEG), in shaping overall satisfaction with remote education. These results highlight the need to embed self-directed learning strategies, teacher guidance, and collaborative practices into accessible KM platforms. While the study was limited to a single case and sample, it offers a foundation for future cross-cultural research and design-based development of scalable, equitable educational models aligned with SDG4 and SDG17.

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