Playful Learning as a Bridge Between Coding and Mathematics in Teacher Education

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Abstract

Recent Italian curricular guidelines emphasize an interdisciplinary approach in STEM education grounded in learning-by-doing and the use of digital and playful resources. Within these guidelines, Informatics is recognized as a conceptual core of Mathematics Education from early schooling, highlighting the need to integrate computational and mathematical thinking from the outset of teacher education. Computational thinking shares key dimensions with mathematical thinking, and Playful Learning can act as a pedagogical bridge between them, supporting disciplinary integration through engaging learning experiences. This qualitative exploratory case study, involving pre-service primary school teachers, examines collaboratively designed digital games on spatial orientation created with the Octostudio app. The instructional design included collaborative prototyping and game design integrating playful dimensions through the Playful Experiences framework. A thematic qualitative analysis of game prototypes and related activities was conducted to identify experiential profiles of designs' playful dimensions and the stimulated cognitive operations through the R-I-Z-A model. Findings suggest that designing playful activities can mediate between content knowledge and promote the development of professional competence.

Keywords: *Playful Learning; computational thinking; mathematical thinking; teacher education; educational game design*

1. Introduction

Computational thinking (CT) entered educational discourse with Wing's [1] seminal Communications of the ACM article and a subsequent elaboration, Wing [2] defined CT as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (p. 20). With this definition, CT is framed as a thought process, not merely as a set of coding techniques, and, more than that, as a fundamental skill for everyone — alongside reading, writing, and arithmetic — thereby grounding the K-12 educational agenda that would follow.

Subsequent scholarship has sought to operationalise Wing's broad vision through more granular taxonomies. Ng and colleagues [3], working within the Mathematics Education community, converge on a four-component characterisation that is particularly useful for primary-school contexts: problem solving, abstraction, pattern recognition, and algorithmic thinking. Hence, CT is understood as a structured form of reasoning that decomposes complex problems, recognises regularities, formulates step-by-step procedures, and evaluates outcomes systematically.

Within the Italian context, where the present study takes place, CT has entered the official educational agenda through successive policy waves. The National Guidelines for the first cycle of instruction [4] already referred implicitly to algorithmic reasoning within Mathematics. More explicitly, the STEM Guidelines [5] and the draft of the New National Guidelines for the first cycle of instruction [6] identify CT and digital literacy as transversal competences to be cultivated from early schooling, recommending playful and hands-on pedagogies. These policy documents resonate with Trinchero's influential position paper [7], which argues that the pedagogical value of CT in Italian primary education resides not in coding per se, but in the opportunity to make children's reasoning processes visible and discussable through the algorithmic activities.

All these institutional changes have brought to the fore the need to prepare primary school teachers to face the newly arisen challenges. And this preparation should start from their academic journey.

The present study aims not only to address emerging future teachers' needs, but also investigates how playful coding activities could be a suitable conceptual space to integrate Mathematics and computational thinking. Participants in this exploratory case study design digital games for primary school kids using the Octostudio app. While future teachers engage in such design processes, they

strengthen their knowledge of disciplinary aspects and reflect on meaningful ways to integrate play, Mathematics, and Informatics into classroom activities.

2. Theoretical Framework

2.1 Playful Learning as a Pedagogical Framing

Playful Learning, which — building on a long tradition of play scholarship from Piaget [8] and Vygotsky [9] through Sutton-Smith [10] — has received a robust contemporary articulation in the influential theoretical piece by Zosh et al. [11]. Zosh and colleagues propose a conceptualisation of play as a spectrum. Guided play has been proven as a uniquely productive configuration for domains — such as spatial thinking — that require both exploratory freedom and conceptual targeting. The theoretical rationale of guided play rests on the "science of learning" pillars [12]: learning is optimised when experiences are active (minds-on), engaging (without being distracting), meaningful, socially interactive, and iterative. Play, when scaffolded appropriately, is a unique cultural form in which these five conditions co-occur naturally.

Within the broader literature on Playful Learning, a growing body of research focuses specifically on the affordances of play and game-based design for STEM education [13]. The argument is twofold. Empirically, STEM content — particularly spatial and algorithmic reasoning — lends itself naturally to enactive, exploratory learning configurations that playful settings support. Theoretically, play establishes the psychological protective frame [14] that allows learners to engage with cognitive risk — to try a solution, fail, iterate — without the affective cost that such failure carries in conventional assessment-oriented settings. For coding in particular, where debugging - recognizing and fixing errors - is a constitutive practice, the protective frame of play transforms errors from stigmatising events into productive resources [15].

Pelizzari [16] articulates a complementary argument within the Italian educational context: playful learning, videogames, and gamification provide pedagogical configurations in which disciplinary content, active methodologies, and affective engagement mutually reinforce one another. For teacher education specifically, Pelizzari argues, engaging pre-service teachers as designers of playful learning experiences — rather than merely as consumers of them — is a privileged route for the development of the pedagogical reflexivity that distinguishes reflective from technical practitioners.

This design-oriented stance resonates with the constructionist tradition inaugurated by Papert [17] and extended by Kafai and Resnick [18], according to which learners construct knowledge most powerfully when they are concurrently engaged in the construction of external, shareable game prototypes. In such a perspective, the prototype is not an outcome but a medium of thought, and its design-oriented manipulation is constitutive of learning itself. For pre-service teachers, this means that designing a game is a learning process — not merely a rehearsal for future teaching.

2.2 Analytical Frameworks: PLEX AND R-I-Z-A

In this study, we adopt two analytical frameworks through which playful experiences and cognitive operations involved in game prototypes will be systematically described: the Playful Experiences (PLEX) framework and the R-I-Z-A model. The choice of these two frameworks is motivated by three considerations. First, both frameworks are designed to capture observable features of learning activity, making them suitable for the thematic analysis of designed digital games that constitute the methodological core of this study. Second, both are decomposable into fine-grained descriptors, which afford sub-categorical analysis. Third, and most importantly, the two frameworks originate in distinct research traditions (experience design and cognitive pedagogy, respectively) and cover non-redundant dimensions (what is experienced and what is done cognitively).

The PLEX framework was initially developed by Korhonen et al. [19] building on a pre-existing pleasure framework for interactive art. Korhonen and colleagues re-grounded the framework on a wider theoretical base encompassing work on pleasurable experiences, game experiences, emotions, elements of play, and the reasons why people play. The revised framework includes 22 experience categories — ranging from Captivation, Challenge, and Completion to Fellowship, Sensation, Fantasy, and Subversion — designed to capture the diversity of playful experiences that interactive products can elicit. In a given interaction, multiple PLEX categories can co-activate, and the presence or absence of one category can reinforce or weaken the others. Moreover, PLEX is proposed not as a fixed checklist but as a scaffold for discussion and ideation, a position that justifies the adaptive, domain-sensitive

selection of six categories — Sensation, Competition, Discovery, Fellowship, Exploration/Experimentation, Fantasy/Narrative — that we adopt for the analysis of primary-school educational games. Although PLEX was originally developed for user experience evaluation, it has been successfully mobilised in design-oriented activities [20] [21]. In teacher education, this design-oriented use is especially relevant: it provides pre-service teachers with a lexicon for articulating the playful qualities they intend to foreground in their digital games, thereby transforming play from a vague motivational attribute into a multi-dimensional, discussable property of the design.

The R-I-Z-A model, developed by Trinchero [7] [22] within the Italian pedagogical tradition of authentic assessment and competence-based education, offers a taxonomy of cognitive operations observable in school learning activities. The acronym, taken from Italian, refers to four nested families of operations: Risorse (Resources, R), Interpretazione (Interpretation, I), aZione (Action, Z), and Autoregolazione (Self-regulation, A). The Resources family (R) includes basic cognitive operations that allow learners to activate and mobilise prior knowledge and to process perceptual input. These operations concern the identification and organisation of relevant elements in a task. They include processes such as recognising, identifying, locating, and selecting. The Interpretation family (I) includes operations aimed at constructing meaning and understanding relationships between elements. These involve analysing information, comparing elements, inferring implicit meanings, and explaining connections within a given context. The Action family (Z) includes active and productive operations through which learners apply knowledge and strategies to perform a task. These include executing, planning, constructing, describing, and classifying. The Self-regulation family (A) includes metacognitive operations that enable learners to monitor, evaluate, and regulate their own learning processes. These include arguing, justifying, motivating, criticising, and finding errors in one's own work.

Trinchero [22] has explicitly mobilised the R-I-Z-A model in relation to computational thinking, arguing that CT-oriented activities offer privileged occasions for the observation of all four families of cognitive operations, provided that the activities are structured so as to render the children's reasoning processes publicly available for discussion.

3. Method

To fulfill the stated research aim, we conducted an exploratory qualitative case study in a Primary Education course in Italy. Participants were eight students, pre-service primary school teachers, in their third year of study. Participants worked collaboratively, split into three groups (G1, G2, G3). They had former experience with designing digital games, offered within the course itself, but they had no prior experience with computational thinking or Octostudio. Octostudio is a free mobile coding app developed by MIT Media Lab [23]. Available on smartphones and tablets, it allows users to create games or other interactive projects. Users are first invited to select a sprite and a background, then directed to the main app interface. The upper part shows the game's backdrop and the sprites involved, the central part is a clean area for block-based coding, and the lower part contains all available blocks, grouped into seven distinct categories, each distinguishable by color. These categories are: starting blocks, motion, words and sounds, scenes, colors and lights, control, and others. Some of these blocks are particularly suitable for integrating playful dimensions into the games. Moreover, created projects can be easily shared and opened by others in the Octostudio app. All these features led us to identify Octostudio as a suitable app for developing playful digital games, compared to other well-known apps such as Scratch. Blocks use an accessible language and rely on intuitive icons. The block shape allows for an easy identification of main, secondary, and intermediate blocks, which can be combined to create instruction sequences.

Prior to the beginning of the classroom activities, participants were administered a short questionnaire, filled in individually, to collect information on their prior knowledge. From their answers, we know that six of them had heard of computational thinking before the experiment, whilst all of them had already heard of coding. Three of them stated they knew what coding is, even though only one out of the three had already practiced it.

The classroom activity lasted in total 2.5 hours. Students were introduced to computational thinking, the selected dimensions of PLEX, and Octostudio. Then the collaborative design phase took place. Students worked all with the same backdrop, depicting a crossroads with a lake in the bottom left corner. Students were requested not only to design a digital game but also to include it within a short educational activity. They were supported in this task by a structured template designed by the researchers themselves, which already provided students with learning objectives from National Guidelines for Mathematics [4] and from the draft of the New National Guidelines [6] for Informatics. These objectives can be formulated as summarized in Table 1, where they are already connected to the cognitive operations outlined in the R-I-Z-A framework.

Math objectives	R-I-Z-A operation	Info objectives	R-I-Z-A operation
Communicate objects position in space	Recognizing and arguing	Examine and interpret simple algorithms	Analyzing
Execute a simple path	Executing	Explain an algorithm and its result	Analyzing
Describe a path or give instructions to someone to follow a path	Arguing and planning	Write an algorithm and translate it into code	Planning and constructing

Table 1. Summary of Mathematics and Informatics objectives of the Italian curriculum connected to R-I-Z-A operations

Students were invited to select their objectives among the listed ones. These prescriptive choices were intended to direct students' efforts towards relevant, playful, and educational elements of the activity. The main interface of the three prototypes is shown in Figure 1. The game design phase was followed by peer feedback: students exchanged their prototype with another group, and they were requested to provide feedback on the other group's game again using the structured template. The activity was concluded by a classroom discussion led by the two researchers.

Fig. 1. Main interface of the three game prototypes. From left to right: "Where is my carrot?" (G1), Little Red Riding Hood (G2), and Let's go to school (G3).

Data collected throughout the activity include pre-questionnaire responses, Octostudio game prototypes, and templates for the playful activity (with game design activity and peer feedback). The research questions we aim to answer are:

1. How can playful coding foster both CT and mathematical reasoning?
2. Which PLEX dimensions and R-I-Z-A operations are most evident in student-designed games?

The qualitative analysis of the collected data was conducted following the six-phase procedure of Braun and Clarke [24]. An inductive categorization of the three prototypes and templates led to the identification of the predominant PLEX dimensions and so to the definition of the experiential prototype profiles. A deductive coding of the R-I-Z-A operations was conducted by triangulating data across design templates, prototypes, and peer evaluations. Finally, the emerging PLEX dimensions salient in the prototypes were associated with a set of typically co-activated R-I-Z-A operations in an integrated map. The qualitative analysis was conducted by the first author and validated by the second.

4. Results

The thematic analysis of the collected data produced a double-layered account of pre-service teachers' design activity: (i) the experiential layer of the playful encounters envisaged by the designers, described through the PLEX framework; and (ii) the cognitive layer, classified according to the R-I-Z-A model, which captures the interpretive, action-oriented, and self-regulatory operations that each prototype makes observable. Such operations refer to those aspects that children-users might engage with while playing with the prototypes and are explicitly connected to disciplinary aspects.

4.1 Experiential Profiles of the Three Prototypes through PLEX

The three developed game prototypes, all targeted at the learning objectives related to spatial orientation, path description, and execution of simple algorithms. An inductive categorisation —

developed through constant comparison across digital prototypes and templates — produced the following PLEX classification, which will serve as the interpretive backbone of the subsequent analysis:

G1 – "Where is my carrot?" is an execution-oriented game. Players guide a rabbit sprite toward a carrot target through directional commands issued under time pressure, with scoring based on execution speed. Mathematics is mobilised in its elementary topological dichotomies (left/right, up/down); computational thinking appears as the execution of short command sequences with immediate feedback (sounds, applause, score increments).

G2 – "Little Red Riding Hood" is a narrative-oriented game. The fairy-tale frame provides a pretext for introducing street signs that function as symbolic constraints on the path: planning the block sequence requires children to interpret conventional signs and translate them into actions executable in Octostudio. Mathematics enters here as symbolically mediated spatial relations, while CT manifests as pre-execution planning and instruction-to-block translation.

G3 – "Let's go to school" is the most explicitly collaboration-oriented prototype. The game simulates the home-to-school bus route and introduces two complementary roles: the navigator, who plans and describes the route verbally, and the driver, who executes the received instructions. This game architecture enforces the decoupling of algorithm design from its execution, rendering the computational process socially distributed and thus observable in its verbalisation.

This inductive categorisation reveals that although the groups started from the same input, the resulting prototypes diverged considerably. Rather than covering all PLEX dimensions, the three groups charted complementary design trajectories, each covering specific PLEX dimensions. This distributional complementarity has pedagogical implications: rather than searching for a single "best" playful design, teacher education may benefit from exposing pre-service teachers to a palette of playful configurations, each carrying a distinct experiential and — as the next section shows — cognitive signature.

4.2 The Activated Cognitive Operations through R-I-Z-A

The R-I-Z-A coding of cognitive operations yielded the synoptic matrix presented in Table 2. Qualitative recurrence is expressed through three intensity levels (✓ present but limited; ✓✓ moderate/recurrent; ✓✓✓ very frequent/central to the game).

R-I-Z-A Descriptor	G1 – Carrot	G2 – Little Red Riding Hood	G3 – School
Recognizing (R – Risorse)	✓ arrows as directions	✓ road signs	✓ school as target
Locating (R – Risorse)	✓✓ positions on the grid using arrows (start/goal)	✓ obstacles and path segments along the route	✓✓ positions and paths in realistic routes
Identifying (R – Risorse)	✓ carrot as target	✓✓ signs as constraints	✓ stops along the journey
Analyzing (I – Interpretazione)	✓ post-game discussion	✓✓ detecting errors with signs	✓✓ cooperative debugging
Arguing (I – Interpretazione)	✓ guided reflection	✓ explaining the signs	✓✓✓ verbalizing the route
Justifying (I – Interpretazione)	✓ "why right?"	✓ route-sign coherence	✓✓ discussed corrections
Executing (Z – Azione)	✓✓ use of arrows to define path	✓ blocks as short sequences	✓✓ driving the bus
Planning (Z – Azione)	✓ trial-and-error actions	✓✓ block sequences	✓✓✓ the path to school

Constructing (Z – Azione)	✓ (limited strategies)	✓ creative use of blocks	✓✓ overcoming obstacles
Finding errors (debugging) (A – Autoregolazione)	✓ wrong arrows	✓✓ incorrect use of signs	✓✓ cooperative correction
Motivating (A – Autoregolazione)	barely evident	✓ goals made explicit	✓✓ navigator motivates choices

Table 2. Summary of R-I-Z-A operations in the three games with associated intensity levels

Table 2 reveals three distinct patterns, each convergent with the corresponding PLEX profile. G1 concentrates strongly on the Locating/Executing axis, i.e. on the procedural-perceptual side of the R-I-Z-A model, with weak activation of self-regulatory structures. G2 redistributes the cognitive centre of gravity onto the Identifying/Planning/Analysing axis: the street signs, as symbolic constraints, require preliminary interpretive work (recognising the symbol as a sign, identifying its rules of use) and sequential planning (ordering the blocks consistently with the constraints). G3 is the only prototype that reaches the ✓✓✓ threshold in two operations (Planning and Arguing), distributed across distinct cognitive structures (Z and A). The navigator role, obliged to verbalise the route in a form that is publicly justifiable to the driver, transforms argumentation from an optional post-hoc activity into a structural device of the gameplay itself.

These patterns empirically substantiate the hypothesis that the ludic architecture of a prototype is not neutral with respect to the repertoire of cognitive operations it makes available — it shapes it in depth [22]. Choosing among an execution-oriented, narrative-oriented, or collaboration-oriented experience determines which R-I-Z-A descriptors find a natural habitat in the game and which remain latent or must be elicited by the teacher's external intervention. This finding has direct consequences for the main claim of the paper: if Playful Learning is to function as a bridge between coding and Mathematics, then the kind of bridge built depends critically on the kind of playful architecture chosen.

4.3 The Integrated PLEX × R-I-Z-A Map

The analytical core of this study lies in the systematic mapping of correspondences between experiential dimensions (PLEX) and cognitive operations (R-I-Z-A). Table 3 presents the integrated map, associating each PLEX dimension salient in the prototypes with a set of typically co-activated R-I-Z-A operations, illustrated with concrete examples drawn from the three games.

PLEX Dimension	**Associated R-I-Z-A Operations**	**Examples from the Games**
Competition	Executing (rapid procedures); Finding errors (quick debug); Calculating (score, moves)	G1: rabbit reaches carrot under time pressure with score; children quickly correct wrong moves.
Sensation	Recognizing (visual/auditory stimuli); Locating (targets in space); Describing (what happened)	G1: applause and the words “right/left” as immediate reinforcement; G3: bus and school graphics to be identified.
Discovery	Identifying (new elements/routes); Hypothesizing (alternative solutions); Constructing (different strategies)	G2: exploration crossroads backdrop and the use of road signs; children try alternative solutions.
Fellowship	Arguing (explaining choices); Justifying (decisions); Organizing (roles and strategies); Planning (sequences together)	G3: the navigator justifies instructions to the pilot; pairs discuss strategies engaging in metacognitive reflection.

Exploration/Experimentation	Analyzing (errors, difficulties); Designing (new procedures); Finding errors (cooperative debugging)	G2: children test sequences of blocks and correct them; G3: if a wrong road is taken, children try another sequence.
Fantasy/Narrative	Describing (stories/routes); Representing graphically (maps); Explaining (causal chains)	G2: children narrate the route; G3: children narrate the journey to school.

Table 3. PLEX × R-I-Z-A map

The integrated map reveals a non-arbitrary, theoretically motivated correspondence between the two frameworks. PLEX dimensions with a strong competitive/sensory component (Competition, Sensation) tend to co-activate operations from the interpretation (I) and action (Z) structures of R-I-Z-A model, especially in procedural form. Dimensions with a strong social and reflective component (Fellowship, Exploration) predominantly mobilise self-regulation (A) operations — those that require verbalisation, justification, and public defence of one's own choices. Narrative and discovery dimensions (Fantasy/Narrative, Discovery) instead bind to operations of construction and hypothesis-formation, positioning themselves in an intermediate zone where mental representation (describing, hypothesising) precedes and informs action (planning, ideating).
A theoretically central implication follows: designing an educational game in PLEX terms is not an isolated aesthetic or motivational choice, but a curricular decision that predetermines the class of cognitive operations the children will be invited to exercise. Choosing to foreground Fellowship in the design necessarily entails a high probability of activating A operations (arguing, justifying); choosing to foreground Competition entails instead a high probability of activating Z operations in rapid, executive form. The two configurations are not hierarchically ordered but functionally distinct, and they require the teacher-designer to make an informed, intentional choice about the cognitive profile the game is meant to promote. In this sense, the integrated PLEX × R-I-Z-A map operationalises the very "bridge" announced in the paper's title: Playful Learning connects coding and Mathematics not generically, but through specific experiential-cognitive pathways that can be consciously selected and designed.

5. Discussion

The first substantive finding of this study concerns the nature of the relationship between computational thinking and mathematical reasoning in the three prototypes. Despite their divergent ludic architectures, the three groups converged on the directions/paths binomial as the conceptual bridge between the two disciplinary domains. This convergence is not accidental: it supports the thesis that computational thinking acts as a boundary object between Mathematics and Informatics [3], with algorithmic thinking functioning as a catalyst for the integration of the two fields. In the created prototypes, the sequential motion of a sprite in space constitutes simultaneously mathematical practice (coordinates, directions) and computational practice (sequence, iteration). The three prototypes differ, however, in the degree of algorithmic explicitness they require of the child. In G1 the algorithm is implicit and instantaneous: children act on the arrows in real time without having to formalise a sequence in advance. In G2 the algorithm becomes semi-explicit: the Octostudio blocks are assembled before execution and can be inspected and modified, but the planning process is individual or tacitly shared within the group. In G3 the algorithm reaches maximum explicitness through the forced verbalisation imposed on the navigator: the sequence must be said aloud, received, understood, and executed by another agent. This gradient demonstrates that the social architecture of the game — rather than the technological features of the platform — determines the level of formalisation and therefore the epistemic quality of the computational thinking activated [11]. On the mathematical side, a parallel enrichment is observed: from elementary topology (G1: right/left as binary oppositions) to spatial symbolism (G2: signs as conventional marks that reorganise space) and finally to everyday geography (G3: real paths, relations between familiar places). This spectrum closely mirrors the Italian curricular guidelines in which primary-school mathematics is reframed as a tool for reading everyday experience rather than as an abstract discipline [4] [5] [6]. Playful Learning, when articulated through carefully designed prototypes such as those analysed here, provides a concrete pedagogical mechanism through which this reframing can be operationalised in teacher education [16].
A second theoretically salient finding concerns the trade-off observed between immediate engagement and cooperative depth. G1 maximises sensory-competitive engagement but sacrifices collaboration; G3 maximises cooperation but pays a cost in experiential fluency; G2 sits in an intermediate position, with

both dimensions under-developed. This triangulation echoes Lazzaro's [25] distinction between hard fun, easy fun and people fun, suggesting that a single game rarely optimises all types of ludic pleasure simultaneously. The trade-off has important didactic implications. If the predominant formative goal is the automation of simple mathematical-spatial procedures (rapid recognition of directions, consolidation of coordinates), an execution-oriented design in the G1 style is not only acceptable but functionally appropriate: competitive reinforcement sustains the repeated practice that automation requires. Conversely, if the goal is the development of metacognitive and argumentative competences, a collaboration-oriented design in the G3 style — even if technically less polished — turns out to be cognitively richer. The design choice is therefore not between a "better" and a "worse" prototype in absolute terms, but between distinct and potentially complementary learning profiles within the broader curricular economy. Notably, the peer evaluation exchanged among groups surfaced this complementarity even in the absence of an explicit theoretical scheme. Peers asked G1 to increase its cooperative component, G2 to strengthen children's agency, and G3 to improve perceptual clarity: each group, in other words, implicitly invited the others to fill their least developed PLEX dimension. This suggests that the PLEX space functions as a shared coordinate system even among designers who have not been formally trained on the framework — an encouraging finding for the pedagogical scalability of the approach in teacher education programmes.

6. Conclusions

The most original contribution of this study, in our view, lies in the combined use of two frameworks that — although rooted in distinct research traditions (PLEX in user experience research; R-I-Z-A in the Italian pedagogical tradition of authentic assessment) — exhibit significant complementarities. PLEX provides a rich vocabulary to describe what happens at the experiential level during playful interaction; R-I-Z-A provides an equally rich vocabulary for describing which cognitive operations that interaction activates. Their combination affords a two-dimensional analysis that neither framework, taken alone, makes possible. Such combination operates in both directions: as a tool of ex post evaluation (question: "given a game and its experience, which cognitive operations are actually activated?") and as a tool of ex ante design (question: "if we want to activate specific cognitive operations, which experiential configurations should we design?"). In the latter sense, Table 3 can be read as a first nucleus of design patterns in the spirit of Arrasvuori et al. [26]: a grammar of correspondences that helps the designer navigate the decision space more consciously.
For initial teacher education, this dual lens offers reflections on what a "cognitively deep game" should be, provides criteria for peer evaluation among pre-service teachers, and enables targeted design iteration: peer feedback can be translated into specific modifications of ludic components. These advantages together support the professional development trajectory foregrounded in the rationale of the study: from Playful Learning as a pedagogical framing, through coding-mathematics integration as a disciplinary bridge, to reflective design practice as a professional competence.

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