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Evaluating the Efficacy of Game-Based Learning on Propulsion Dynamics and Water Adaptation in Novice Swimmers

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Abstract Background: In alignment with Uzbekistan's national initiatives to expand youth mass sports, optimizing early-stage aquatic education is a critical public health objective. Traditional post-Soviet training methodologies, frequently utilized in regional specialized sports schools, heavily emphasize mechanical repetition. In arid regions like Karakalpakstan, where youth have limited early exposure to deep water, this rigid approach often exacerbates aquaphobia.

Objective: This study investigates the impact of active aquatic games versus traditional direct instruction on propulsion dynamics, spatial awareness, and water adaptation among novice swimmers.
Methodology: A 9-week pedagogical experiment was conducted involving 40 novice swimmers (ages 6–9) at a Specialized Children's and Adolescent Water Sports School (SCAWSS) in Nukus. Participants were divided into a Control Group ($n = 20$) receiving standard instruction, and an Experimental Group ($n = 20$) engaging in a Game-Based Learning (GBL) protocol. Changes were measured using the Water Orientation Test (WOT) and hydrodynamic efficiency metrics (stroke count over 10 meters).
Results: The Experimental Group exhibited a statistically significant improvement in water adaptation, extending buoyancy duration by an average of 4.2 seconds compared to the Control Group ($p < .01$). Furthermore, GBL participants achieved a 14% reduction in stroke frequency over 10 meters, indicating enhanced distance per stroke (DPS).
Conclusion: Active games serve as a highly effective pedagogical tool for mitigating early aquatic anxiety and accelerating hydrodynamic self-organization. Integrating GBL into the primary curricula of Uzbekistan's youth water sports schools is recommended.

1. Introduction

The systematic development of youth sports and the promotion of mass physical culture are central pillars of state policy in the Republic of Uzbekistan. Following the recent adoption of the updated Law "On Physical Culture and Sport" (ZRU-1123) in 2026, there is a renewed mandate to modernize youth training protocols to improve athletic retention (Ministry of Sport, 2026).

Historically, swimming education in Uzbekistan's Specialized Children's and Adolescent Sports Schools has relied heavily on traditional, direct-instruction methodologies (TSSIM)[^1] inherited from post-Soviet physical culture paradigms (Platonov, 2015). While effective for elite technique refinement, rigid mechanical drills present distinct disadvantages for complete novices. This issue is

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particularly pronounced in the Republic of Karakalpakstan. Due to the arid climate and the ecological constraints of the Aral Sea region, many youth in Nukus lack early, unstructured play experiences in deep water. Consequently, initial aquatic exposure in a formal setting often triggers acute aquaphobia, manifesting as vertical body posturing and muscular tension (Morais et al., 2020).

Recent global pedagogical shifts advocate for Game-Based Learning (GBL) and Ecological Dynamics, proposing that movement is learned implicitly through environmental interaction rather than explicit coaching (Rudd et al., 2021). This study aims to quantify the efficacy of active games on early water adaptation and propulsion dynamics, providing a modern, localized pedagogical framework for aquatic instructors in Uzbekistan.

2. Literature Review

2.1 Post-Soviet Aquatic Pedagogy vs. Ecological Dynamics

The traditional methodology utilized in regional sports schools focuses heavily on isolated, land-based mimicry and rigid repetitions (Khasanov, 2021). However, the Ecological Dynamics framework argues that early specialization via repetitive drills stifles motor creativity. By utilizing a Constraints-Led Approach (CLA), coaches can manipulate environmental tasks (e.g., game rules) to guide athletes toward discovering optimal hydrodynamic solutions organically, without forced mechanical compliance (Light, 2014; Rudd et al., 2021).

2.2 Psychophysiology of Aquaphobia and Play

Fear of water induces chest tension, rapid respiratory rates, and a breakdown of natural buoyancy, which drastically increases hydrodynamic drag (Barbosa et al., 2011). Gamification mitigates this response by acting as a powerful external cognitive distractor. Vygotsky's (1967) foundational theories on play suggest that when a child focuses on achieving a game objective, the sympathetic nervous system downregulates. Recent studies confirm that embedding problem-solving games into physical education lowers stress and promotes faster cognitive-motor adaptation (Coppola et al., 2024; Pelaez et al., 2000).

2.3 Hydrodynamics and Novice Propulsion

Biomechanical efficiency in swimming relies on horizontal alignment and maximizing Distance Per Stroke (DPS). Novices typically exhibit high stroke frequencies with minimal forward velocity—a phenomenon known as "slipping" (Seifert et al., 2007). Play-centric pedagogies that implicitly encourage long, relaxed movements are critical for developing DPS before formal mechanics are introduced (Zoitova, 2023).

3. Methodology

3.1 Participants

The experiment was conducted at a SCAWSS facility in Nukus, Karakalpakstan. The cohort comprised 40 youth swimmers (ages 6–9; 22 male, 18 female) with no prior formal swimming instruction. Participants were randomly divided into an Experimental Group (EG, $n = 20$) and a Control Group (CG, $n = 20$). Written consent was obtained from parents/guardians.

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3.2 Organization of the Study

The pedagogical intervention spanned 9 weeks (three 45-minute sessions per week).

Control Group Protocol: Followed the standard institutional curriculum. Instruction was highly directive, utilizing kickboards, stationary gutter-breathing exercises, and isolated stroke repetitions.

Experimental Group Protocol: Utilized an active GBL curriculum. Tasks included Submersion Games (e.g., "Aral Sea Pearl Diver"—retrieving weighted rings to develop breath control) and Evasion Games (e.g., "Amudarya Sturgeon"—tag games designed to implicitly foster rapid propulsion and horizontal alignment)[^2].

3.3 Data Collection

Pre- and post-intervention measurements were recorded:

Water Orientation Test (WOT): A standardized psychomotor assessment measuring aquatic comfort (Langendorfer & Bruya, 1995)[^3]. Scored out of 10 points based on facial submersion, unassisted starfish floats, and independent recovery.

Propulsion Dynamics: Evaluated via a 10-meter unassisted freestyle swim. Total time (seconds) and stroke count (number of arm cycles) were recorded to calculate implicit biomechanical efficiency.

4. Results

Data were processed using SPSS Statistics v.28. Following Shapiro-Wilk tests for normal distribution, paired and independent t-tests were utilized ($p < .05$).

4.1 Water Adaptation (WOT Scores)

Baseline WOT scores showed no statistical difference between groups. Post-experiment, the EG demonstrated significantly greater morphofunctional adaptation.

Group	Pre-Test WOT (Mean ± SD)	Post-Test WOT (Mean ± SD)	Absolute Improvement
Control Group	3.1 ± 0.6	7.0 ± 0.8	+ 3.9 points
Experimental Group	3.0 ± 0.5	9.8 ± 0.4	+ 6.8 points

Note: The EG sustained relaxed buoyancy in the float test for an average of 12.4 seconds, compared to the CG's 8.2 seconds ($p < .01$).

4.2 Propulsion Dynamics (10-Meter Swim)

Both groups improved their time, but biomechanical strategies differed significantly, indicating superior efficiency in the EG.

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Group	10m Stroke Count	10m Time (seconds)
Control Group	22 ± 3 strokes	16.4
Experimental Group	17 ± 2 strokes	15.1

5. Discussion

The findings strongly support the hypothesis that active games serve as a superior methodology for establishing foundational aquatic mastery.

The CG, trained via traditional isolation drills, exhibited high stroke frequencies over 10 meters, indicating a reliance on rapid, inefficient energy expenditure ("slipping"). Conversely, the EG developed a significantly better Distance Per Stroke (DPS) without receiving explicit mechanical instruction. During evasion games like "Amudarya Sturgeon", children self-organized their movements; to escape a tagger, they instinctively discovered that stretching out horizontally and pulling water rhythmically is faster than frantic splashing. This perfectly illustrates the Ecological Dynamics theory (Rudd et al., 2021).

Furthermore, the GBL protocol rapidly dismantled aquaphobia—a critical barrier for youth in arid regions like Nukus. By shifting cognitive focus away from the intimidating environment and onto an engaging task, children bypassed physiological stress responses, leading to superior WOT scores and prolonged buoyancy (Coppola et al., 2024; Langendorfer & Bruya, 1995).

6. Conclusion

The methodology of organizing swimming mastery using active games demonstrates profound efficacy in early-stage athlete preparation. Gamified pedagogy accelerates psychophysiological adaptation to the water and implicitly develops superior hydrodynamic movement patterns compared to traditional direct instruction. To align with national goals for physical culture development (ZRU-1123), it is recommended that specialized water sports schools across Uzbekistan integrate active games as the primary mechanism for foundational aquatic instruction.

Footnotes

[^1]: **TSSIM (Traditional Sports School Instruction Method):** Refers to the standard, linear pedagogical progressions (e.g., dryland mimicry followed by isolated kickboard use) traditionally favored in regional Specialized Children's and Adolescent Sports Schools across post-Soviet states.

[^2]: **Regional Game Adaptations:** Standard aquatic games were localized to the Karakalpakstan context to increase cultural resonance and participant engagement. "Aral Sea Pearl Diver" utilizes weighted rings for submersion practice, while "Amudarya Sturgeon" is a variation of traditional evasion/tag games.

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[^3]: **Water Orientation Test (WOT):** A criterion-referenced observational checklist. It quantifies a novice's comfort level and spatial awareness before formal competitive swimming strokes are introduced, ensuring the absence of the sympathetic nervous system's "fight or flight" response.

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