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GAMIFIED, TECHNOLOGY-ENHANCED GEOMETRY AND SYMMETRY INSTRUCTION FOR LEARNERS WITH INTELLECTUAL DISABILITIES: A DESIGN-BASED STUDY IN A GREEK SPECIAL SCHOOL

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Abstract:
Geometry and symmetry are fundamental for navigating the world, yet many students with intellectual disabilities (ID) still struggle to fully understand these concepts. This eight-week, three-cycle design-based study explored whether a low-cost blend of gamification and readily available educational technologies could make these concepts more accessible in a Greek Special Vocational Education Laboratory (special secondary school). Six lower-secondary students with moderate ID (mean age = 14.8 years) co-designed and iteratively refined a toolkit that mixed GeoGebra-AR explorations, tablet mini-games, classroom Kahoot challenges, interactive-whiteboard puzzles, and tactile "mirror-tracing" tasks. Preliminary testing showed limited recognition of basic shapes and almost none of reflective symmetry. By the end of the intervention, median correct answers on a 20-item shape test increased from 8 to 17, while symmetry-awareness scores on a 15-item rubric climbed from 4 to 11. Observational checklists documented a steady rise in on-task engagement—from 2.5 to 3.6 on a four-point scale—echoed by "happy-face" exit tickets in almost nine out of ten sessions. Learners also began spontaneously mapping virtual forms onto classroom artefacts (e.g., "This ball is a sphere"), hinting at transfer from the digital to the physical world. Because this approach was applied in a single classroom with a few students, the results cannot be generalised. Even so, they hint that three elements—quick feedback, friendly competition, and presenting ideas in

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several formats—can together lift understanding for learners with intellectual disabilities. Working side-by-side with the students to shape each activity also seemed to give them a stronger sense of ownership and prompted them to think about how they learn, a step often missed but crucial for lasting progress. Future studies should focus on applying the same approach in larger groups, play with different game features, and test whether carefully structured practice helps these improvements hold and grow over time.

Keywords: special education; gamification; educational technology; geometry; intellectual disability

1. Introduction

Everyday spatial missteps—taking a wrong turn in the school corridor, mistaking a hex-nut for a circle, or placing floor tiles out of alignment—underscore how demanding geometric and symmetry concepts remain for adolescents with intellectual disabilities (ID). Solid evidence links mathematical competence to everyday independence, employability, and broader adaptive functioning (Powell *et al.*, 2025). Yet large-scale Greek monitoring still finds that barely one in three students attending Special Vocational Education Laboratories can correctly name three basic plane shapes when they graduate. A survey of 102 pupils enrolled in Greek Special Vocational Junior High Schools showed that only about one-third — 32 % — could accurately name three everyday plane figures (circle, square and triangle) at the end of their compulsory studies (Chrisikou, 2011).

Classic chalk-and-talk lessons rarely close that gap. Students with ID often need concrete--representational--abstract progressions and strong visual cues; static diagrams struggle to provide either (Arvanitaki & Zaranis, 2020). Augmented-reality overlays, dynamic-geometry environments, and tightly scoped mini-games, by contrast, can magnify salient features, offer error-controlled practice, and let learners replay tricky steps at their own pace (Navas-Bonilla, Guerra-Arango, Oviedo-Guado, & Murillo-Noriega, 2025). Meta-analyses in mainstream settings point toward sizeable gains when game mechanics—points, leaderboards, timed quests—are layered onto mathematics tasks; however, most of those studies centre on arithmetic, not shape or symmetry (Yani & Rosma, 2020).

Closer to home, early design work shows promise. For instance, a sustainability-themed serious game piloted with corporate learners produced marked concept growth and a noticeable uptick in eco-friendly talk around the water-cooler (Karachalios, 2024). Similar cross-domain spill-overs appear in school-based projects on waste management (Karachalios & Manesis, 2025) and open educational resources that weave vocational storylines into environmental topics (Armakolas, Robolas, Karachalios, Anastopoulou, & Gomatos, 2019). These findings hint—but do not yet prove—that playful, context-rich digital experiences might also untangle the abstractions of lines, angles, and mirror images for students with ID.

The empirical record, though, remains patchy. Systematic reviews flag a shortfall of classroom-embedded studies on geometry and symmetry for adolescents with moderate ID, especially within the Hellenic context (Sunzuma, 2023). Sample sizes are tiny, interventions often last a single week, and few reports track whether pupils can transfer screen-based insights to the real objects they handle every day. Such gaps make it hard for teachers—and policymakers—to sort enticing gimmicks from genuinely workable practice.

Against this backdrop, we adopted a design-based approach in one Greek Special Vocational Education Laboratory (E.E.E.E.K.). Working with six lower-secondary students, we iteratively co-crafted a low-cost toolkit that blends dynamic-geometry apps, tablet micro-games, tactile mirror tasks, and short outdoor photo hunts. Two research questions guided the work:

1) What changes, if any, appear in learners' recognition of geometric shapes and symmetry after three cycles of gamified, technology-enhanced instruction?
2) Which design features seem to sustain engagement and encourage students to apply new ideas beyond the screen?

By foregrounding co-design and everyday artefacts—think cola cans as cylinders or butterfly wings as bilateral mirrors—we aim to inch the evidence base closer to the lived realities of Greek special-education classrooms.

2. Literature Review

Grasping why a cola can counts as a cylinder—or why butterfly wings match across a mid-line—remains a tall order for many adolescents with intellectual disabilities (ID). Static diagrams and one-way explanations rarely bridge that gap. Augmented-reality geometry lessons in Greek primary schools, for instance, boosted visualisation skills only when virtual objects could be spun, re-sized, and inspected from several angles (Arvanitaki & Zaranis, 2020). Yet even these promising trials stopped short of symmetry or older learners.

2.1 Digital Geometry for Learners with ID

Systematic reviews tell a similar story. Across 29 studies, dynamic-geometry environments such as GeoGebra outperformed paper-and-pencil tasks on concept change, but only a fraction involved secondary pupils with moderate ID (Sunzuma, 2023). Tablet-based manipulatives look helpful—students pinch, drag, and rotate shapes without fine-motor strain—yet sample sizes seldom climb past twelve participants (Navas-Bonilla *et al.*, 2025). Those gaps leave teachers guessing which features matter most: tactile feedback, colour contrast, or simply novelty.

2.2 Gamification and Motivation

Adding game mechanics usually nudges learning outcomes upward, yet effect sizes still vary markedly across studies. A recent meta-analysis of 71 experiments involving more

than 5,000 learners reported a large overall benefit for gamified instruction (Hedges g = 0.82), although geometry tasks accounted for fewer than 5 % of the comparisons examined (Li, Ma, & Shi, 2023). Reviews that concentrate on students with disabilities strike a more cautious tone: points, badges and leaderboards do attract attention, but they are also the game elements most often linked to motivational dips or outright frustration when challenges are not carefully scaffolded (Almeida, Kalinowski, Uchoa, & Feijo, 2023). Mini-games limited to five-minute rounds appear safest; they lift engagement without overwhelming working memory (Polydoros & Antoniou, 2025).

Within Greece, gamification research has centred on environmental education rather than mathematics. A workplace sustainability game, for example, doubled correct post-test scores while sparking corridor talk about recycling (Karachalios, 2024). Similar spill-overs surfaced in school waste-management projects that paired quizzes with real-world sorting drills (Karachalios & Manesis, 2025) and in pre-service-teacher courses that wove scenario-based missions into lectures (Karachalios & Tantaroudas, 2025). These studies hint that playful competition and immediate feedback should translate to geometry, yet that leap has not been tested empirically.

2.3 Inclusive, Context-Rich Pedagogy

Beyond scores, inclusive-technology frameworks urge designers to anchor abstract ideas in students' lived worlds. Open educational resources co-created with Greek vocational teachers—e.g., a sustainability module on up-cycling furniture—showed higher completion rates when activities referenced local trades (Armakolas *et al.*, 2019). Classroom observations from the present project echo that advice: learners talked more when screenshots of classroom doors (rectangles) preceded on-screen grids. Evidence-based teaching guides likewise advocate explicit modelling, scaffolded practice, and rapid formative checks—elements that align naturally with brief, low-stakes digital quizzes. Recent empirical work underscores the value of this trio: video-based explicit instruction has been shown to boost sixth-graders' online credibility-evaluation skills (Kiili, Kiili, Räikkönen, & Coiro, 2025); a systematic review of 41 K-12 studies concluded that scaffolded interventions are most successful when support is continuously diagnosed, responsively adjusted, and gradually faded (Dominguez & Svihla, 2023); and a learning-analytics study found that weekly e-quizzes accounted for roughly one-third of the variance in university students' final-exam scores (Bulut, Gorgun, & Yildirim-Erbasli, 2025). Still, reviews flag a shortage of studies where digital tasks are embedded long enough for transfer beyond the screen (Sunzuma, 2023).

2.4 Research Gap and Present Study

To date, no Greek investigation has woven game-styled geometry, symmetry, and tangible classroom artefacts into a sustained programme for adolescents with moderate ID. Prior work offers tantalising leads—use augmented reality to magnify folds, keep game rounds brisk, and let students photograph their own "cylinders" or "mirror lines"—but stops short of a classroom-embedded, multi-cycle design. The present study

picks up that gauntlet, asking whether a co-designed, low-cost toolkit can (a) raise geometric and symmetry mastery and (b) foster the kind of ownership that turns screen victories into real-world noticing.

3. Material and Methods

3.1 Study Design

We adopted a design-based research (DBR) methodology that unfolded over three four-week iterations—**Shape Discovery**, **Everyday Symmetry**, and **Symmetry in Nature**—each comprising planning, enactment, reflection, and redesign. The iterative structure mirrors the *expansive-learning* cycle, in which interventions and analyses spiral outward to create new practices and local theory (Engeström & Sannino, 2021).

Recent DBR work in mathematics education confirms that such cycles help researchers trace causal mechanisms while still permitting real-time task adjustments (Komatsu, Shinno, Stylianides, & Stylianides, 2025). Methodological advances—most notably *learning-experience network analysis*—show how data from one round can drive principled micro-revisions in the next without sacrificing ecological validity (Donaldson, Han, Yan, Lee, & Kao, 2024). Parallel multi-year DBR projects with students who have disabilities further underline the need to fine-tune digital tools and collaborative routines in response to learner feedback to keep motivation high across iterations (Alverson, Bell, Parra, & Wei, 2025).

Guided by these insights, every cycle in our study followed the same rhythm—an *immersion trigger* (short video or photo hunt), a *hands-on or digital exploration*, a *timed mini-game*, and a *conversational de-brief*—while the precise media, prompts, and scoring algorithms were iteratively refined using student analytics and post-session focus-group insights.

3.2 Participants and Setting

Six Grade-A learners (4 males, 2 females; age 13–15) attending a Greek Special Vocational Education Laboratory (E.E.E.E.K.) volunteered after parental consent. All held formal moderate-ID diagnoses (IQ ≈ 40–55) and followed the national adapted mathematics curriculum. Sessions took place thrice weekly in an ICT room outfitted with one interactive whiteboard, six Android tablets, reliable Wi-Fi and a drawer of tactile shape blocks. The first author—also the class teacher—facilitated every session, a choice that may colour observations but boosted continuity.

3.3 Instructional Materials

- **Digital tools**
  - *GeoGebra AR* for free-hand rotation and scaling of prisms and pyramids.
  - *Wordwall* drag-and-drop matchups (Cycle 1) and timed flips (Cycle 2).
  - *Kahoot* quizzes with muted leaderboards to keep competition friendly (Cycles 2–3).

  - An open-source mirror-simulation on the whiteboard to spotlight bilateral folds.
- **Tactile and local props.** Cola cans (cylinders), biscuit boxes (rectangular prisms), small mirrors, and student-snapped photos of schoolyard butterflies—an echo of the "everyday anchor" tactic championed in Greek waste-education projects (Karachalios & Manesis, 2025).

3.4 Instruments

Table 1: Overview of assessment instruments, item formats, intended constructs and reliability indices

Measure	Items/scale	Purpose	Reliability
Shape–Object Matching Test	20 colour photos	Plane/solid recognition	KR-20 = 0.81
Symmetry Identification Test	15 images	Mid-line detection	KR-20 = 0.79
Teacher Observation Rubric	3 domains × 4-point Likert	Engagement, vocabulary, help-seeking	Inter-rater = 0.86 (pilot)
Emoji Exit Ticket	4 icons	Affective snapshot each lesson	—

Rubrics and image banks were adapted from earlier environmental-game studies (Karachalios, 2024) to keep layout and response mechanics familiar.

3.5 Procedure

1) **Cycle 1 – Shapes.** Short "Find My Shape!" role-play with household packages opened the unit; tablet tasks followed, capped by a Wordwall speed-round (90 s).
2) **Cycle 2 – Basic Symmetry.** Learners drew digital mirror lines on the whiteboard, then raced through Kahoot prompts that mixed correct/near-miss examples.
3) **Cycle 3 – Symmetry in Nature.** A guided outdoor photo walk (photo-walk) outside yielded butterfly-wing and leaf shots; back in class, students overlaid symmetry axes and shared quick captions.

Formative tallies (quiz accuracy, observation scores, exit-ticket mood) were tabulated each Friday, nudging minor tweaks—e.g., slower reveal of leaderboard points when enthusiasm outpaced understanding.

3.6 Data Analysis

Given the tiny sample, we favoured non-parametric statistics. Pre–post shifts on both tests ran through Wilcoxon signed-rank procedures (α = .05). Qualitative notes were coded deductively (attention, discourse, help-seeking) and then re-read for surprises. Where a code straddled category—say, a student naming a "sphere" while nudging a ball toward a peer—it was double-tagged to keep nuance.

3.7 Ethical Considerations

Parents signed opt-in forms; students could skip any activity without penalty. Pseudonyms cloak identities, and all digital artefacts sit on a password-protected drive. The study followed national guidelines on special-needs research and drew informal inspiration from participatory action protocols used in other research surveys (Karachalios, Plakitsi, *et al.*, 2023).

4. Results and Discussion

Shape knowledge showed a statistically significant increase. On the 20-item Shape–Object Matching Test, the group median jumped from **8 correct answers at baseline to 17** after Cycle 3 (Wilcoxon $Z = –2.20$, $p = .028$, **r = 0.90**). Symmetry identification followed a similar arc: median scores rose from **4 to 11** out of 15 (Wilcoxon $Z = –2.07$, $p = .039$, **r = 0.85**). Three of the six students doubled their symmetry tally.

Engagement told its own, quieter story. Weekly observation rubrics crept from a mean of **2.5 → 3.6** (on a 4-point scale). Emoji exit tickets echoed the trend: "happy face" selections appeared in 89 % of sessions, up from 62 % in the first fortnight. Qualitative notes add colour. G. paused during Cycle 2 to point at a cola can: "Teacher, this is a cylinder—see, two circles and a body." M., who rarely volunteers, traced an air-conditioning grille with her finger while muttering, "many rectangles." Such moments cropped up 18 times across the final six lessons, compared with just three sightings in the opening week.

No adverse events surfaced. Two tablets froze briefly during a Kahoot round, but students toggled to the whiteboard version without fuss. Attrition was nil; attendance held at 100 %, perhaps helped by the Thursday photo-walks that many labelled "a weekly highlight".

The numbers suggest the mixed-media, game-tinged approach can spark real movement in geometric thinking for adolescents with moderate ID. A nine-point increase on the Shape–Object test lines up, direction-wise, with smaller gains reported in earlier Greek environmental-game pilots (Karachalios, 2024). While those studies focused on recycling trivia rather than angles and faces, the common thread—immediate feedback wrapped in playful competition—appears to travel.

A likely reason is that the activity gave students a tangible anchor: they took their own photos of butterfly wings and then drew the mirror line directly onto those images, turning symmetry from an abstract idea into something they could literally see and manipulate. Similar everyday-object hooks have boosted completion rates in open educational resources on sustainability (Armakolas *et al.*, 2019). The present data cannot prove causality, yet the timing—spikes in symmetry scores after the photo-walk cycle—does invite the hypothesis.

Engagement metrics climbed, but the ceiling was not hit. The muted Kahoot leaderboard placated M., who fretted about "losing," yet D. later murmured that he "missed the fireworks." Balancing friendly rivalry with safe space may remain a moving

target—a nuance echoed in pre-service-teacher gaming research (Karachalios & Tantaroudas, 2025). We may need adaptive point displays or peer-versus-self modes to keep both risk-averse and thrill-seeking students engaged.

Transfer outside the screen was modest but noticeable. Spotting cylinders in soft-drink cans signals more than rote recall; it suggests budding *spatial noticing*. Still, no learner independently referenced rotational symmetry, a gap mirroring earlier waste-education findings where pupils talked recycling yet balked at composting details (Karachalios & Manesis, 2025). Future cycles could weave in short outdoor hunts for rotational patterns—car wheels, fan blades—to flesh that out.

Several limitations hover. The sample is tiny and site-specific; a single enthusiastic teacher (the first author) wore both designer and facilitator hats. Fresh eyes might see flaws we missed. In addition, Wilcoxon tests safeguard against distribution quirks but say nothing about long-term retention. A delayed post-test would add heft. Finally, tablets glitched only twice, yet reliable Wi-Fi cannot be assumed in every Greek special-vocational setting; any scale-up must budget for contingencies.

Even with those caveats, the study nudges the conversation forward. It hints that low-cost, co-designed digital kits, anchored in students' own photos and classroom artefacts, **can** move the needle on geometry and symmetry for a population often overlooked in mathematics research. Whether the gains stick into adulthood—or carry into budgeting, carpentry, or map reading—remains the next question on the board.

5. Recommendations

Successful geometry teaching for adolescents with intellectual disabilities seems to hinge less on expensive software and more on how ordinary objects, quick games, and teacher improvisation line up during the school day. The present findings, together with earlier Greek studies on sustainability games and waste-management projects, point toward five intertwined principles.

First, concepts stick when lessons start from the learners' own surroundings. Asking students to photograph cola cans, classroom tiles, or butterflies and then trace outlines or mirror lines on their images transformed symmetry from an abstract idea into something they could literally point at. Comparable "everyday anchors" lifted completion rates in an open educational-resource module on vocational sustainability (Armakolas *et al.*, 2019) and boosted post-test scores in a school waste programme (Karachalios & Manesis, 2025).

Second, micro-sized game rounds—three to five minutes of timed matching or Kahoot quizzing—keep attention high without overloading working memory. In our classroom, median engagement rose steadily once sessions were broken into these bite-sized bursts, echoing the pattern reported in a corporate sustainability game where short quests doubled learning gains (Karachalios, 2024). Friendly competition helps, but tempering leaderboards prevents anxious learners from checking out early.

Third, learning deepens when tactile, digital, and verbal modes are blended in the same lesson. A typical forty-minute block might flow from tablet rotations of prisms to real-world mirror tracing with cardstock, to a two-minute "geometry reporter" chat where a pupil explains a newly spotted shape. Multimodal runs like these mirrored the design of a teacher-student co-creation study that saw robust improvements in sorting accuracy during waste-management drills (Karachalios, Plakitsi, *et al.*, 2023).

Fourth, co-design is not a luxury. When students could tweak scoring speeds or vote for different photo-hunt themes, observation scores climbed more quickly—an echo of the strong ownership effects logged in a pre-service-teacher gamification project (Karachalios & Tantaroudas, 2025). Monthly "game-hack" afternoons, where pupils revise one classroom rule and test it the same week, would institutionalise that voice.
Finally, the cleverest app is useless when the Wi-Fi drops. Low-tech contingencies—a shoe-box full of wooden solids, laminated QR cards linking to offline GeoGebra files—kept our lessons moving during two brief outages. Similar belt-and-braces planning underpinned the continuity of the WWSS23 e-learning summer school, which mixed live streams with downloadable booklets to side-step bandwidth gaps (Karachalios, Kalavrouziotis, *et al.*, 2023).

Taken together, these principles sketch a pragmatic roadmap: begin with everyday artefacts, teach through short playful cycles, fuse multiple modes, let students steer design decisions, and always pack a low-tech parachute. None of these steps guarantees mastery, yet the cumulative evidence suggests they nudge geometry and symmetry from perplexing abstractions toward concepts learners can recognise, name, and—crucially—use beyond the screen.

6. Conclusion

This design-based study tracked how a compact blend of tablet activities, short game rounds, and everyday artefacts influenced lower-secondary learners with moderate intellectual disabilities in a Greek Special Vocational Education Laboratory. Over eight weeks, median correct responses rose from **8 → 17/20** on a shape-recognition test and **4 → 11/15** on a symmetry rubric. While the sample was limited to six students, these gains echo prior Greek work in sustainability gaming that also recorded sizeable post-test jumps under feedback-rich, playful conditions (Karachalios, 2024; Karachalios & Manesis, 2025).

Three design principles appear to underlie the observed progress. First, grounding tasks in learner-generated photographs—cans, tiles, butterfly wings—helped translate abstract geometry into tangible reference points, reinforcing findings from open educational-resource projects that tied content to local vocational contexts (Armakolas *et al.*, 2019). Second, restricting each game segment to brief three-to-five-minute "micro-bursts" sustained attention and avoided unnecessary working-memory load; moderator analyses in two recent meta-studies report the largest cognitive gains when gamification is delivered in short, feedback-rich cycles (Li *et al.*, 2023; Sailer & Homner, 2020). Third,

iterative co-design—students could delay the leaderboard reveal or swap photo-hunt themes—nurtured the collective agency and reflective dialogue emphasised in expansive-learning theory (Engeström & Sannino, 2021) and is mirrored in recent pre-service-teacher research on gameful learning design (Guberman & Smith, 2021; Karachalios & Tantaroudas, 2025).

From a practical standpoint, our findings suggest that meaningful geometry instruction does not require high-end hardware. A handful of tablets, free GeoGebra-AR files, and commonplace classroom items can yield measurable conceptual growth—provided lessons remain short, multimodal, and genuinely student-steered. Nevertheless, the evidence is preliminary. Replication across multiple Greek special school settings, delayed retention checks, and expansion into rotational symmetry and 3-D reasoning are the necessary next steps. Such work would clarify whether context—urban versus rural, bandwidth-rich versus bandwidth-poor—moderates the impact documented here and would help distil a scalable, evidence-informed model for inclusive geometry education.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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