From Novice Players to Creative Designers: A Constructionist Attempt with SorBET

From Players to Designers with SorBET

Maria-Stella Nikolaou[1], and Chronis Kynigos[1]

[1] National and Kapodistrian University of Athens, Greece

Abstract
This paper presents a small-scale, exploratory study investigating how eight middle school students shifted from passive engagement to reflective designers of their own learning experiences. Utilizing "SorBET", a digital tool that enables learners to both play classification-based games and modify their underlying structures, students were observed through three phases: initial gameplay, adaptive modifications and eventual design of new game content within a design-based research (DBR) framework. The intervention involved two distinct interaction modalities: one group of students engaged with gesture-based and voice-command interface, while another group employed a traditional mouse-based interface. The study explores how iterative experimentation, external feedback and reflection contribute to the development of active, creative participation, as well as how different interaction methods influence collaboration and decision-making. Findings suggest that embodied interactions tend to prioritize rapid iteration, though this sometimes came at the cost of explicit negotiation. Mouse interfaces more often led to structured deliberation, though individual dominance varied. While limited in scope, this study offers valuable insights into the integration of constructionist principles in game-based learning environments and emphasizes how such experiences empower learners to critically engage with the logic and structures behind digital tools.

Keywords and Phrases: Constructionism, Classification-Based Games, Interactive Learning, Collaborative Design

1. Introduction
Digital educational games have long been considered effective educational tools, offering immersive environments that engage students in active learning experiences. Yet, much of the existing literature on game-based learning treats learners as consumers of predesigned content and there is comparatively less attention on how students might reshape or even redesign such environments. From a constructionist standpoint, learners develop deeper understandings when they can build, revise and share artifacts that reflect their evolving concepts and personal interests (Papert, 1980; Kafai & Resnick, 2012; Kynigos, 2020). This study investigates whether minimal scaffolding and open-ended digital tools encourage students to adopt more "designerly" ways of thinking, particularly in the context of classification-based games. The research examines how two different interaction modalities, gesture-based and

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voice-command interfaces versus traditional mouse input, influence collaborative decision-making, reflection and game modification practices. Specifically, it attempts to explore three key questions:

RQ1: How do the different input modalities (gestures and voice versus mouse) shape students' interaction with digital tools and what challenges or opportunities arise from each?

RQ2: In what ways do students collaborate and negotiate decisions during their early experiences with the technology?

RQ3: How do students' classification strategies evolve through iterative gameplay, reflection, and design modifications in SorBET and to what extent does this process foster deeper engagement in game design?

By analyzing students' dialogues, gestures and game design choices, this study provides preliminary evidence on how such environments can shift learners from passive gameplay to active participation in system design, a critical aspect of constructionist learning paradigms.

2. Theoretical Background

2.1 Constructionism and Experiential Learning

This study builds on constructionism (Papert, 1980), which posits that learners construct knowledge most effectively when they are actively engaged in creating meaningful artifacts that reflect their evolving understanding and personal interests. Rather than viewing students as passive recipients of information, constructionism invites them to construct artifacts, test hypotheses, and share their evolving ideas (Kynigos, 2020). While pure constructionist approaches emphasize building systems from fundamental components (Resnick & Silverman, 2005), SorBET adopts a scaffolded approach, where students repurpose pre-designed elements to lower initial barriers while still engaging in iterative design (Kynigos 2004, 2020). This approach aligns with Alan Kay's vision of computational tools as amplifiers of human thought (Kay, 1993), later formalized in constructionist contexts as 'tools for thought' – where pre-designed elements serve as cognitive catalysts rather than constraints (Kynigos, 2020). The digital tool initially presents classification games as pre-constructed "black boxes" with fixed rules and interfaces, lowering initial barriers for novice learners. Through its edit mode, SorBET gradually reveals these systems as configurable "white boxes", allowing students to modify game logic through block-based programming and category redesign. This progression embodies what Kynigos (2020) later formalized as "half-baked constructionism", where learners evolve from users to designers through iterative engagement – first experiencing ready-made systems, then adapting their parameters and ultimately authoring new configurations.

This approach also aligns with Kolb's (1984) experiential learning theory, which views learning as a continuous process grounded in experience. According to this theory, knowledge emerges through a dynamic cycle of experience, reflection, conceptualization and experimentation. The structure of this study, progressing from initial gameplay to adaptive modifications and finally to the design of new game content, closely mirrors this iterative process. By engaging students in hands-on interactions and encouraging reflection on their strategies and outcomes, the intervention provided opportunities for learners to integrate experience with conceptual understanding.

2.2 Classification-Based Games and Conceptual Development

Games that require classification tasks have a special place in educational contexts (Grizioti & Kynigos, 2024). At first sight, they often appear simple: objects are classified into categories based on specific criteria (such as 'years of decomposition' or 'types of nutrients'). However, classification tasks often encourage deeper reflection on how knowledge is organized within a domain. They challenge learners to think critically about the rules and criteria that define categories and to consider exceptions or ambiguities (Medin & Smith, 1981). For example, an item labelled as 'plastic' may rightly be placed in the '>200 years' category for decomposition, but certain biodegradable plastics may complicate this logic. Constructivist approaches to classification games thus allow learners to challenge the game content themselves, modifying or expanding it to represent personal or newly discovered meanings (Grizioti & Kynigos, 2024). By modifying or expanding such games, learners take an active role in shaping their understanding, fostering a sense of ownership and critical engagement with the subject matter. This process aligns with the constructionist emphasis on learning through creation and exploration, where learners build frameworks that reflect their evolving insights and discoveries. Building on the work of Annett (1959), who identified developmental stages in classification behaviors and methods of explanation, this study explores how reflective engagement with classification-based games can foster deeper conceptual understanding. Annett's findings, which emphasize the role of experience and the evolving sophistication of classification strategies, provide a foundation for investigating how learners transition from concrete pairings to abstract reasoning within a game-based, constructionist framework.

2.3 Collaboration, Interaction and Multimodal Interfaces

The study examines how SorBET's two input modalities – gesture/voice versus mouse interfaces – shape collaborative learning processes through their distinct affordances. Drawing on Human-Computer Interaction (HCI) research (Rogers & Lindley, 2004; van Beurden et al., 2012), mouse-based interactions typically foster structured, turn-based collaboration, often leading to role differentiation and verbal negotiation, while gesture/voice interfaces promote spontaneous, embodied interactions through parallel input channels. Existing research emphasizes the critical role of interaction modalities in shaping group dynamics. For example, multimodal interfaces that support simultaneous inputs have been found to enhance collaboration by allowing parallel contributions and reducing conflicts over control (Rogers & Lindley, 2004). However, the extent to which these findings apply to educational contexts, particularly those involving younger learners, remains an open question. By observing how learners interact under each condition, this research seeks to provide empirical insights into the relationship between interaction design, shared control and collaborative engagement in such constructionist learning environments.

3. The Digital Authoring System "SorBET"

SorBET[1] (Sorting Based on Educational Technology), designed by Educational Technology Lab, can be considered a constructionist tool, combining classification gameplay with game design capabilities (Grizioti & Kynigos, 2024). As players, users categorize falling objects (images/text) into labeled boxes (Figures 1a,1d), receiving real-time feedback and a scoreboard for reflection. In the edit mode, users as designers can import images, define which categories they belong to (including multiple correct ones) and even program adjustments in gameplay difficulty via block-based programming (Figures 1b, 1c). This dual design-play structure fosters student agency by bridging classification mechanics with creative modification. Recent developments have extended SorBET's interaction capabilities beyond the mouse. Utilizing webcam-based hand tracking, the digital system can detect gestures for pushing objects, which enables two players to interact simultaneously. Additionally, voice-commands functionality allows users for dynamic parameter adjustment, such as speed or density of falling objects, detecting catchphrases from device's microphone, like "faster" or "more".

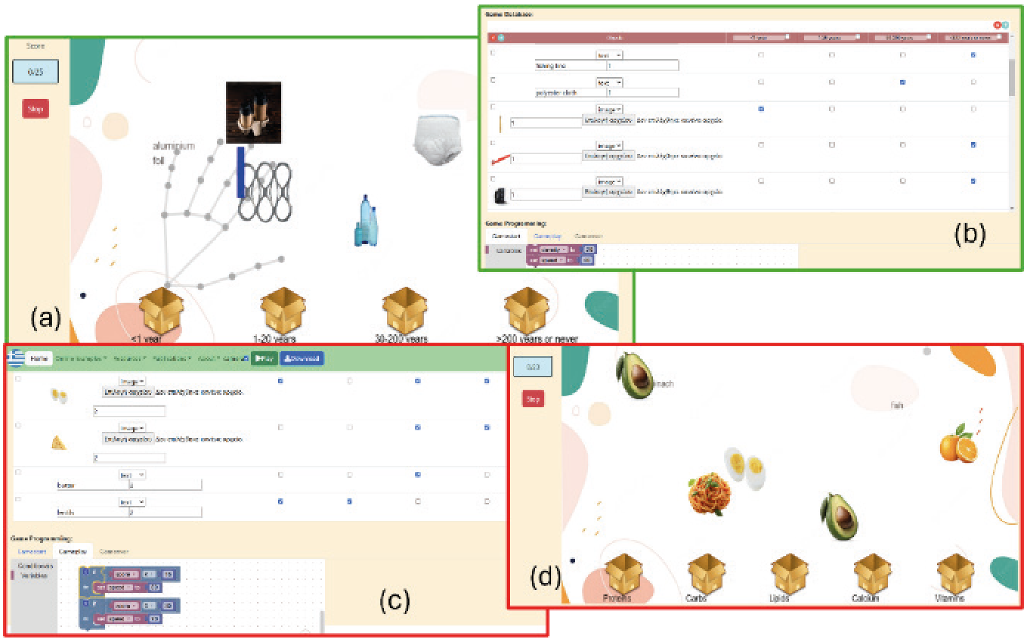

Figure 1: SorBET Tool's Environment. "How Long for Degradation" game in (a)Play Mode using hand-detection and (b) in Edit Mode. "Nutri Ninja" game in (c) Edit Mode and (d) Play Mode.

4. Intervention design and methodology

4.1 Design-Based Research Framework

This study follows a Design-Based Research (DBR) approach (Barab & Squire, 2004), characterized by iterative cycles of design, implementation and refinement in authentic learning environments. DBR bridges the gap between theoretical constructs and practical applications by situating interventions in real-world contexts and refining them through continuous observation and feedback. The intervention described here is part of a larger ongoing research initiative aimed at investigating how constructionist tools like SorBET can foster reflective learning, collaboration and data literacy among students. This specific phase of the research focuses on

1 http://etl.ppp.uoa.gr/sorbet/

exploring the interplay between interaction modalities, collaborative processes and the development of design-oriented thinking in middle school learners. By observing and analyzing the interactions across three phases – gameplay, adaptive modifications and creative design – this study contributes preliminary insights that will inform the next cycles of intervention refinement and broader implementation within the overarching research framework.

4.2 Participants and Setting

Eight middle school students (N=8), aged 13-14, participated in this cycle of exploratory study, intentionally selected for depth of qualitative analysis over statistical generalizability (Barab & Squire, 2004). They were divided into two main groups, each employing different interaction modalities: Group X students interacted in pairs through gestures and voice commands (two pairs labeled X1 and X2) (Figures 2a,2b), while Group M students used a mouse (two pairs, M1 and M2) (Figures 2c,2d). The setting was a computer lab with laptop computers, in an extracurricular setting, and the intervention lasted two sessions, five hours in total.

The study comprised three phases. In Phase 1, students engaged with a simple predefined classification game called "How Long for Degradation?" (Figure 1a) with straightforward, non-overlapping categories, about the years needed for everyday objects to decompose naturally. The categories were year timespans (e.g. "<1 year", ">200 years or never" etc.) and objects from different materials (e.g. plastic/wooden toothbrushes, tires, coffee cups etc.). Their focus was on experimenting with the basic mechanics of the game and understanding feedback (correct vs. incorrect classification). In Phase 2, students encountered another game, "NutriNinja", where familiar foods as objects (such as "cheese", "avocado", "eggs" etc.) could be placed in more than one category associated as nutrients (i.e. "carbs", "vitamins" etc.) (Figure 1d). The students were encouraged to play both games as many times as they wanted, noting down their scores each time. All participants worked in pairs, with students from group X playing simultaneously using their hand gestures through a hand tracking system from their laptop's web camera (Figures 2a,2b), while students from group M shared the mouse in a traditional version of SorBET (Figures 2c,2d). In the second phase, parameters of the game such as speed and density of the falling objects were gradually being adjusted. The adjustment from group X occurred using voice commands (e.g. "faster/slower" or "more/less"), while students from group M were assisted by the researcher to adjust the speed and density from the game's edit mode. Eventually, in Phase 3, all groups were introduced to SorBET's edit mode, first to add new objects, invent categories and experiment with block-based coding (Google Blockly) to regulate difficulty for the existing game and then, to freely design their own version of the game for other players of their age, taking on the role of designer. In the final stages of design, students swapped places and tested each other's game by providing verbal informal feedback (Figure 2e).

4.3 Data Collection and Analysis

Data included screen recordings, audio captures of discussions and video capture of interactions, researcher's notes and students' final game designs. Furthermore, pre- and post-survey questionnaires were given regarding participants' experience with technology. Adhering to a qualitative thematic analysis approach, the researcher identified and coded critical incidents across all three phases of the study (Viergever, 2019). In this context, a "critical incident" refers to any notable moment that exemplified or shifted students' reasoning, collaboration, or data-handling strategies – such as disputes over classification logic, spontaneous reassignments of category labels, or the adoption of new game parameters.

Initially, researcher focused on incidents linked to classification logic (e.g., confusion over multi-category items, evolving decomposition heuristics), collaborative negotiations (e.g., how pairs resolved input-control conflicts or handled disagreement) and design thinking (e.g., adjusting speed or density in Phase 2, reassigning entire category sets in Phase 3). Once coding for Phase 1 was complete, the same analytical framework was applied to Phases 2 and 3, enabling the study to trace how naive strategies gradually evolved into more nuanced parameter manipulations and creative design choices. Throughout this process, two researchers triangulated the transcribed audio, final game states and reflection sheets to ensure consistency and reliability in interpretation.

Following an open coding pass, recurring references to aspects such as "interface-driven collaboration", "classification rationale", "negotiation of design" and "data literacy" were refined into higher-level themes aligned with the research questions (RQ1, RQ2, and RQ3). These themes served as an analytic scaffold, linking specific incidents (e.g., conflicts over hand-gesture control, voice-command speed adjustments, multi-category labeling) to broader conceptual categories (interaction modalities, collaborative processes and emergent design thinking). The Findings and Analysis section that follows draws upon these coded episodes to highlight key shifts in student behavior and understanding across the three phases.

Figure 2: (a,b) Groups X1 & X2 interacting using hand gestures (c,d) Groups M1 & M2 interacting using mouse (e) Phase 3 where students test each other's game.

5. Findings and Analysis

This section presents findings in relation to the three research questions, drawing on a thematic analysis of critical incidents observed in participants' communication, screen captures, researcher's notes and final game artifacts. Each RQ is addressed with references to Phases 1, 2, and 3 to highlight how learners' behaviors evolved over time.

5.1 RQ1: Input Modalities and Student Interaction

From the outset, learners experienced distinct interaction dynamics tied to their assigned input modality. Data from Phase 1 revealed that gesture-and-voice groups (X1, X2) began with considerable uncertainty and occasional technical glitches, yet quickly discovered that embodied interaction enabled them to move objects simultaneously. This was most visible in Group X1, where students initially struggled to calibrate the webcam-based hand tracking. However, once resolved, the embodied aspect of hand tracking led to direct, parallel control. Students could spontaneously take action if they disagreed with a partner's classification. An illustrative exchange from Group X1 (Table 1) revealed how tangible gestures sometimes substituted for lengthy verbal negotiation. Student X1.2 insisted on placing an item (a specific piece of plastic) in the "never" decomposition time category, while the other student recalled that a prior similar attempt had been marked incorrect. Rather than debate further, X1.1 physically dragged the item into the "30-200 years" bin, even if X1.2 had initially tried to handle it during gameplay. This dynamic underscores the opportunity for simultaneous input to facilitate direct experimentation but also reveals a challenge: gesture-based teams risked bypassing conceptual negotiation in favor of "doing first, discussing later". Meanwhile, the mouse-based groups (M1 and M2) often dealt with sequential input constraints. In Group M1, one participant dominated the mouse while the other merely offered suggestions. This arrangement sometimes marginalized the "advisor", yet it also encouraged more explicit verbal articulation of classification logic. For example, Student M1.2 would carefully explain why "plastic" belonged in a longer time category, prompting the mouse-handler to consider or refute this reasoning before acting, yet the student controlling the mouse typically had the final say. In M2, where control was alternated each round, partners commented that the act of passing the mouse forced them to articulate their thinking to each other. By Phase 2 – centered on "NutriNinja" game – the divergence in input modalities became even clearer: gesture-voice teams could shout "Faster!" or "Slower!" to adjust difficulty on the fly, producing a dynamic cycle of overshoot and correction, whereas mouse teams had to open the edit menu and decide on a single setting to implement manually. Although this process was more methodical, it frequently yielded deliberate discussions about how fast was "too fast", reflecting a slower but more reflective approach to game pacing. In Phase 3, when students were free to modify the last game "NutriNinja" or come up with new ideas for others to play, the input modality influenced their design decisions and discussions. Groups X1 and X2 had in mind that these games would be played under the same interactions they encountered as players (i.e. body movements and voice commands) something that influenced their design. This assumption led them to spend less time coding speed or density adjustments in the Blockly environment. As one member of Group X1 explained, "They can just say 'Faster!' if they get bored, so let's not waste time adding all these conditions". Another chimed in, "They'll be shouting 'Slower!' soon anyway", implying that real-time voice commands would suffice to fine-tune the game's difficulty. This reliance on embodied inputs meant the group focused more on designing visually interesting game content for them (i.e. objects and categories) rather than elaborating complex rules in code. In contrast, the mouse-based groups (M1 and M2) prompted more deliberate conversations about how the software itself should dynamically adjust speed or difficulty. Group M2, for example, spent considerable time iterative debugging and scripting specific thresholds for the falling objects: "Let's do: if score >10, set speed to 40; if >15, then 60... we want it challenging", explained one student, while another added, "But not too frustrating, so maybe we only jump to 70 after 20 points". These step-by-step decisions emerged, with Group M2 explicitly referencing scenarios like, “What if they’re really good? Should we push speed up sooner?”. Although both modalities encouraged students to tune the game for potential users, the gesture-and-voice teams leaned on real-time bodily adjustments, whereas the mouse-based groups coded more discrete, pre-planned parameter changes.

Student	Transcript	Notes
X 1.2	„Never“ is the appropriate category for this. Come on, come on, quick!’	Moves hand to place the item in the “Never” bin, insisting on immediate action.
X 1.1	“We tried ‘Never’ before, and it was wrong...”	Reaches across, intercepting the item before it lands in “Never” category.
X 1.2	“But it’s plastic; it doesn’t decompose!”	Continues to hover near the screen, still trying to nudge the object towards “Never”.
X 1.1	“Nope, I’m sure, I’m taking it. We’re putting it in ‘30-200 years’!”	Grabs and drags the item away from X1.2’s control, dropping it into “30-200 years” category.
X 1.2	(Brief pause) “Fine... I guess we’ll see”	Pulls hand back, momentarily conceding as the game registers the classification.

Table 1: Critical Incident from Group X1.

5.2 RQ2: Collaboration and Negotiation in Early Encounters

Collaboration and negotiation took different forms across the three phases. In Phase 1, for example, one gesture-based group (X1) settled classification disputes through physical overrides: a student would snatch control of an object to place it in a favored bin, resolving disagreements swiftly but with minimal joint reasoning (Table 1). Meanwhile, the mouse-based Groups (M1 and M2), also from Phase 1, had to negotiate which student operated the mouse and how they would incorporate each other’s suggestions. In Group M1, one participant dominated mouse usage, occasionally ignoring or downplaying the second student’s inputs. Group M2 followed a more balanced approach, alternating control and verbally discussing item properties such as “if the material is plastic, maybe we put it at 30 years”. In Phase 2, negotiation centered on parametric changes, such as voice-adjusted speeds in Group X1 or Group M2’s collective debate over multi-category items like “lentils”. Some groups researched uncertain facts online, illustrating a shared pursuit of clarity. In Phase 3, all teams used the same edit mode to co-create new categories and item sets, but they still displayed distinct collaborative habits shaped by their earlier experiences. Gesture-based pairs, having previously enacted quick moves during gameplay, tended to propose bold changes such as unexpected category labels – then seek peer validation. For instance, Group X1 replaced their “heart attack” category only after the other student stated that outsiders found it unclear. Their negotiation style involved short bursts of feedback (“Too weird, let’s rename it”) followed by immediate action in the edit interface. Meanwhile, mouse-based groups like M2 conducted step-by-step discussions before altering speed thresholds or dropping items from the game, ensuring each partner’s perspective was heard. These focused micro-negotiations, like “Is it too confusing to have multiple labels here?”, led to careful compromises. Across all teams, peer input and external testing served as catalysts. Whether using gestures or a mouse, students consistently negotiated category boundaries, justified or modified speed thresholds and balanced personal preferences with the anticipated needs of future players.

5.3 RQ3: Emerging Classification Strategies and Game Design

The analysis of students' classification strategies revealed a progression from heuristic-based sorting to more structured, context-sensitive classification models, mirroring cognitive processes described in Medin & Smith's (1981) study. Initially, students relied on superficial heuristics, making broad generalizations such as "plastic lasts forever" or "wood decomposes faster". These early classification attempts were trial-and-error driven, shaped by the game's immediate feedback which guided iterative refinements. Group M2 explicitly noted in their worksheets that they "used errors as a guide", underscoring the role of feedback loops in refining category distinctions and debugging process. By Phase 2, students demonstrated a more nuanced understanding of classification logic, particularly as they encountered multi-category legitimacy in the "NutriNinja" game. This phase prompted students to question binary classifications (e.g., whether lentils belong in "calcium" or "iron" or both), resembling the exemplar-based approach (Medin & Smith, 1981), where learners use similarity-based comparisons rather than rigid rules. Several groups cross-referenced real-world nutritional data, signaling a shift toward data literacy and evidence-based classification. All teams also experimented with modifying speed and density parameters to align with classification difficulty, illustrating how abstract conceptualization in Kolb's (1984) learning cycle supported the refinement of classification as a dynamic, context-sensitive process. This cycle was particularly evident also in Phase 3, where students not only modified game logic but also provided peer feedback, refined their designs, and iteratively tested gameplay conditions. More specifically, in Phase 3, students accessed SorBET's edit mode to design original categories and tweak block-based code, effectively authoring the logic they had previously only followed. Students from Group X1 initially added funny, uncommon objects (e.g., "caviar" and "energy drinks") or unfitting categories (like "heart attack"), then refined them under peer critique, ultimately settling on "iron" as a more precise category label. Group X2 re-themed their game around "home-cooked", "junk food" and "sweets" categories, testing whether food choices like "black chocolate", or "fried chicken" should be placed in more than one categories. Group M2, which had started with a balanced mouse-sharing dynamic, leveraged this design freedom by adding visual elements, stating "Let's add a picture with nuts; it's more visually appealing, or even better let's turn every object into image" and debated whether certain foods should belong to one or multiple categories. As they tinkered with these ideas, they self-regulated the complexity of their game; for instance, opting to keep pepper solely in "vitamins" rather than allowing multiple labels, to avoid overwhelming future users. They introduced a tiered speed mechanism triggered after certain score thresholds: "If score >10, set speed = 40; if score >15, speed = 60", reflecting a logical, data-driven approach to difficulty scaling. A parallel shift was observed in Group M1, where one previously passive student (SM1.2) who had "preferred to watch" in earlier phases suddenly developed a keen interest in testing and playing the new version of the game. Upon finalizing the design with custom labels and speed thresholds, SM1.2 exclaimed, "I actually want to test the game now that we made it. It feels more like ours", implying a heightened sense of ownership and investment once they had contributed to the game's logic. This evolution from passively watching to actively refining and then eagerly participating exemplifies the constructionist principle that learners often gain deeper engagement by building, modifying, and taking responsibility for shared artifacts (Papert, 1980; Kafai & Resnick, 2012; Kynigos, 2020).

6. Conclusion and Future Directions

This study provides preliminary insights into how eight middle school students transition from passive players to active designers when engaging with SorBET, a classification-based game environment grounded in constructionist learning principles (Papert, 1980; Kafai & Resnick, 2012; Kynigos, 2020). Through iterative gameplay, reflection, and design modifications, students demonstrated a progression from naive categorization heuristics to more structured classification engagement. Their learning process, shaped by feedback loops and collaborative negotiation, aligns with Medin and Smith's (1981) exemplar-based classification model, where learners refined their understanding by iterating on classification structures and modifying parameters. Initially, students relied on broad generalizations, often misclassifying objects based on intuitive but imprecise reasoning. However, as they repeatedly engaged with the game's mechanics, they began to experiment with category overlaps, challenge binary classifications and consider multi-dimensional classification criteria, reflecting a growing sense of data literacy and computational thinking. The study also highlighted how different input modalities influenced the way students approached classification tasks and collaborative decision-making. Gesture-based teams exhibited dynamic, parallel control, allowing immediate classification actions but sometimes bypassing in-depth verbal negotiation, whereas mouse-based groups engaged in structured deliberation before implementing decisions, leading to more methodical game refinements. While embodied interaction fostered fluid, exploratory engagement, mouse-based interactions encouraged pre-planned modifications, with students deliberately scripting parameter thresholds. These findings suggest that interface design shapes not only user interaction but also the cognitive and social dimensions of game-based learning (Rogers & Lindley, 2004; van Beurden et al., 2012), raising questions about how to balance intuitive interaction with deeper conceptual reasoning in future learning environments.

As a small-scale pilot within a design-based research framework, this study opens several avenues for further exploration, albeit the small sample size (N= 8) precludes broad generalizations. Future research could expand the participant pool and investigate the long-term impact of classification-based game design on students' ability to analyze and refine data structures across different domains. While students in this study demonstrated emerging data literacy skills, further studies should examine whether these skills transfer beyond the immediate gaming context to broader computational and scientific practices. Additionally, expanding SorBET's implementation to diverse educational settings and age groups could provide insight into how learners of varying experience levels engage with open-ended classification design. Additionally, expanded research should control social and demographic factors, such as prior technology experience and collaboration styles, to isolate constructionist learning effects more precisely. The current findings suggest that gesture-based interaction encourages direct experimentation, yet may limit opportunities for explicit reasoning, while structured input methods promote deliberation but may slow spontaneous discovery. Future iterations of SorBET could explore hybrid approaches that integrate structured reflection prompts or adaptive scaffolding to support deeper engagement with classification reasoning (Kolb, 1984). Additionally, increasing SorBET's flexibility as a game authoring tool could provide students with greater autonomy in defining classification logic, refining feedback mechanisms, and integrating real-world datasets. This would further align with the constructionist emphasis on learning through creation, as students would not only engage with classification but actively design new systems of organization, fostering critical engagement with data structures and user-centered design considerations (Grizioti & Kynigos, 2024).

To conclude, this study offers initial evidence that classification-based game design can serve as an effective medium for developing data literacy, computational thinking, and collaborative problem-solving skills. By shifting from players to designers, students engaged with classification as an evolving, context-sensitive process rather than a static set of rules. While this study represents an early step in understanding these dynamics, the findings underline the need for further research into how digital game design can scaffold students' ability to manipulate, analyze and design data-driven learning experiences. As interactive learning environments continue to evolve, incorporating both embodied and structured approaches to game-based classification could offer new pathways for supporting students as active participants in shaping their own learning experiences.

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