

A Study of Game Design for Children's Maths Anxiety Intervention

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ABSTRACT

The Ph.D. research investigates cognitive-motivational imbalances in game-based interventions targeting children's math anxiety. Utilizing embodied cognition theory, the researcher devises games to address children's math anxiety, proposing a game design framework grounded in embodied cognition for intervention purposes. The study empirically assesses the effectiveness of this design in mitigating math anxiety among children and incorporates longer-term experimental observations to evaluate its impact on reducing anxiety, enhancing math performance, and potentially altering children's cognitive and social behaviors.

CCS CONCEPTS

• **Human-centered computing** → **Laboratory experiments**; **Empirical studies in HCI**.

KEYWORDS

Maths Anxiety, Embodied Cognition, Game Design, Child Education

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1 INTRODUCTION

Mathematics is vital in education and STEM fields, causing psychological pressure due to its abstract nature, leading to anxiety among students[13]. Maths anxiety, categorized into trait and state anxiety, is prevalent globally[29][8][12]. In the US, 93% of adults experience maths anxiety[5]. In the UK, 30% of adolescents face severe maths anxiety[14]. A study in 34 OECD countries found 59% of 15- to 16-year-olds worry about difficult maths lessons[24]. With digital advancements, games aid math anxiety interventions[23][30].

Given the intricate cognitive and emotional dimensions of math anxiety, there's a gap in understanding how games can effectively address it. While existing research acknowledges the potential of

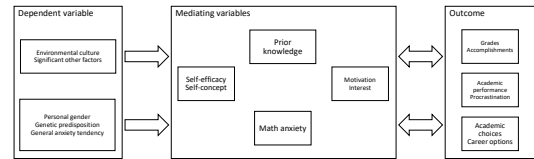


Figure 1: Understand maths anxiety

gamified learning environments, more focus is needed on the mechanics of games to impact math anxiety. It's suggested that games designed solely for math anxiety interventions may have a greater impact on academic performance rather than reducing math anxiety. Therefore, there's a need for further research to develop games tailored specifically for this purpose.

1.0.1 Maths Anxiety. Studies[16] find that maths anxiety induces emotional responses like nervousness and annoyance, impairs working memory function, and manifests in physiological symptoms such as increased heart rate and dizziness[7]. While previously viewed as distinct, maths anxiety is now recognized as an integrated construct encompassing both emotional and cognitive dimensions. The framework (Fig.1) for math anxiety includes antecedents like upbringing, culture, and education system characteristics. In the learning process, self-efficacy, self-concept, and motivation interact with math anxiety. Math anxiety influences grades, behaviors, and life choices, forming developmental outcomes with long-term effects.

1.0.2 Children. Piaget's Genetic Epistemology[25] delineated four developmental stages in children's psychology: perceptual-motor (0-2 years), pre-operational (2-7 years), concrete-operational (7-12 years), and formal-operational (12-15 years)[15]. In China, most children start compulsory education at age 6, with schooling divided into early-middle and last-school stages[9]. Math anxiety research initially focused on university and high school students, but shifted to children in the 21st century. Studies indicate that math learning difficulties begin early, with anxiety accumulating over time[3]. Cognitive strategies vary among children with different levels of math anxiety, exacerbating with age[13]. Math anxiety leads to avoidance behaviors, hindering skill development[7]. Preventative measures and interventions for childhood math anxiety are increasingly advocated[3]. This study targets children aged 10-13 (grades 5-7).

1.0.3 Learning Games and Gamified Learning. Serious games and gamification utilize game mechanics and design methods to enhance experiences outside of entertainment contexts. Research in

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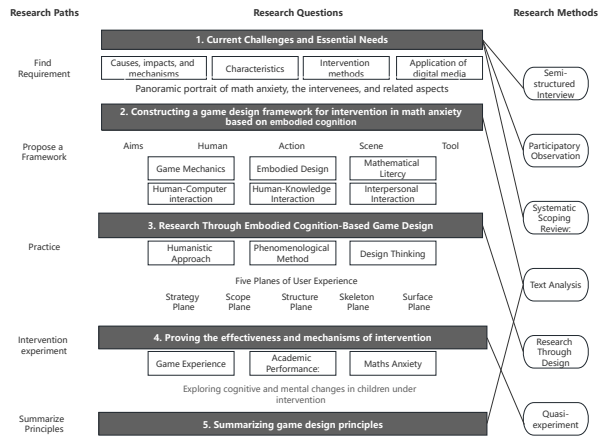


Figure 2: A Study of Game Design for Children's Maths Anxiety Intervention

this field, building on digital game design methods, has diversified into education, science, sports, and healthcare over the past two decades. The serious games specifically designed for educational purposes are often named learning games. Gamified learning involves integrating gaming elements and mechanics into non-game activities within an educational environment to enhance learning motivation and engagement. The aim of this study is to design mathematics learning games with the purpose of intervening in math anxiety.

1.1 Research Questions

Q1: What are the current challenges in gamified interventions for children's math anxiety and math learning game design? What are the essential needs of teachers, students, and parents, and where are the opportunities for gamification and embodied design?

Q2: How can virtual environments integrate with embodied cognition and game interaction for math learning and anxiety interventions? How should the elements of embodied cognition game design, like mechanics, goal setting, challenge difficulty, physical interaction, feedback, and educational utility, be structured to meet stakeholders' needs?

Q3: How effective is an embodied cognition-based game system in addressing children's math anxiety, considering physical interaction and mathematical literacy? Can the study's validity be established across diverse age groups and for prolonged use?

Q4: What cognitive and behavioral changes occur in children's math learning due to the game's use for anxiety intervention? Are there observable alterations in other aspects of learning and socialization during long-term experiments?

2 RESEARCH DESIGN AND METHODS

- **Systematic Scoping Review:** A comprehensive review of existing research will be conducted to analyze maths learning games and gamified maths anxiety interventions through an embodied design lens.
- **Needs-Gathering Study:** Semi-structured interviews and focus groups will be utilized to gather insights from students,

parents, and teachers regarding the potential for learning games and interaction design addressing maths anxiety.

- **Embodied Cognition-Based Game Design:** Through Research through Design methodology, a framework for maths anxiety interventions will be explored. A learning game will be designed and developed based on previous research findings. Sixth and seventh-grade students will participate in experiments, divided into an embodied cognition group and a non-embodied control group. Regular assessments using the Maths Anxiety Scale, participant observation, and semi-structured interviews will be conducted. Data will be coded to identify core themes and refine the design framework, proposing effective design strategies.
- **Observation and Interview Coding:** Analysis of observations and interviews from the intervention phase will provide insights into children's academic, social, and cognitive behavioral changes resulting from the interventions.

3 WORK SO FAR

3.1 Interventions for maths anxiety

To study maths anxiety interventions, I searched the WOS core library using keywords "Reducing", "Remediation", "Addressing", and "Intervention", along with "Math Anxiety" and "Mathematical Anxiety". From 173 papers, 54 were retained after abstract review. After full-text assessment, 14 articles meeting intervention criteria with clear effects were included from the last 10 years. The 14 papers (Table 1) reveal that interventions for math anxiety primarily focus on emotional or cognitive dimensions, with some addressing both. Commonly validated approaches include gamification, expressive writing, MAGMAreappraisal, tutoring, contextualized lessons, parental involvement, and peer learning. These interventions span learning and non-learning environments, including face-to-face and remote settings.

Expressive writing, MAGMA and reappraisal, validated across various studies and populations, offer cost-effective interventions. They aim at emotion regulation, effective for general anxiety, yet their efficacy for math anxiety hinges on math-related context and assessment. Gamification, tutoring, and accompaniment demand expertise, mainly targeting trait math anxiety, requiring multiple interventions for noticeable effects over time.

3.2 Research on Embodied Cognition

Beilock[4] in "How the Body Knows Its Mind: The Surprising Power" mentions that "emotions are rooted in the body" ... "The body has a huge influence on the mind. Whether it's learning at school, being creative at work, or succeeding on the playing field or stage, there are countless examples of physical experiences that influence our thinking." The author suggests that the connection between our minds and our bodies is not a one-way street. We can use our bodies, movements, and surroundings to change our own thoughts as well as the thoughts of those around us.

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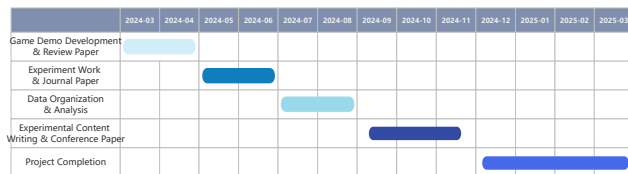
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Table 1: Review of maths anxiety interventions

Literature	MA Measure	Intervention
Ng, Chen et al. [23]	CMAQ	Gamification
Pizzie, Kraemer et al. [26]	Academic performance	Reappraisal & Study Skill
Lital, Orly et al. [10]	sMARS	Reappraisal
Samuel, Buttet et al [32]	AMAS	MAGMA
Rahe, Quaiser-Pohl et al. [28]	AMAS	Mental Rotation
Pizzie, McDermott et al. [27]	fMRI, AAI, AAI-Math	Reappraisal
Zuo, Wang et al. [34]	Maths grades	MAGMA
Mavilidi, Ouwehand et al. [18]	CATQ	Physical Exercise
Donolato, Toffalini et al. [11]	AMAS	Self-resilience
Rozgonjuk, Kraav et al. [31]	5-item MAQ	Self-efficacy
Brewster, Barbara et al [6]	sMARS	Expressive Writing
McCarty, Lindsey et al. [19]	General Q&A	Expressive Writing
Moliner, Alegre et al. [22]	MASC	Peer Tutoring
Rincon-Flores, Santos-Guevara et al. [30]	Self-designed Questionnaire	Gamification

Table 2: Review of Research on Embodied Cognition

Points	Summary
Bidirectional body-mind relations	Beilock highlights the influence of physical experiences on thinking, emphasizing a two-way interaction[4].
Historical views vs. embodiment	Historical views (Aristotle, Descartes) contrast with Merleau-Ponty's[20, 21] embodiment theory.
Rejecting Cartesian dualism	Dewey and James advocate for cognition shaped by interaction with the world, rejecting mind-body separation[2, 17].
Gestures reduce math anxiety	Studies suggest gestures like fist clenching reduce math anxiety and enhance learning[33].
Embodied math learning approaches	Abrahamson[1] explores embodied approaches to math learning, developing tools like the mathematical image trainer.

**Figure 3: Ph.D Project Schedule**

Their assistance has been instrumental in shaping my research direction.

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