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Doctoral Colloquium—Designing Inclusive Game-Based Informal-STEM Learning for Neurodiverse Middle-School Learners

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Abstract. This Gaming 4 Good (G4G) work-in-progress project aims to enhance participation and success in STEM education for individuals with disabilities (IWD) by using video game design as an educational tool to teach computational thinking (CT) and foster positive STEM identities. Recognizing the diverse challenges faced by IWD, G4G adopts a transdiagnostic approach, focusing on shared experiences rather than specific diagnoses to create an inclusive learning environment. The project takes place in informal settings, such as after-school programs and summer camps, where students participate in extended game jams to develop and design video games. Through these hands-on activities, learners engage in data practices, systems thinking, and collaborative problem-solving, making STEM learning accessible and engaging for neurodiverse populations. By continuously involving IWD, their caregivers, and subject matter experts in the co-design process, G4G ensures that the program meets diverse learning needs and is applicable in real-world settings. Ultimately, G4G seeks to empower IWD by fostering their interest and skills in STEM, thereby creating pathways for their success in future opportunities.

Keywords: Video Game Design, Co-design, Neurodivergence, Transdiagnostic, Informal STEM Learning.

1 Introduction

Despite growing efforts to promote diversity, equity, and inclusion in STEM (Science, Technology, Engineering, and Mathematics) fields, individuals with disabilities (IWD) remain significantly underrepresented in STEM education [1]. Numerous barriers continue to hinder their full participation in STEM learning environments, including lack of mentorship, insufficient support systems, and inadequate inclusive instructional practices [2]. While there is growing awareness of these barriers faced by individuals with physical disabilities (e.g., visual, auditory, and motor impairments), there remains a considerable gap in supporting those with neurodevelopmental and learning disabilities [3]. Conditions such as autism, ADHD, and dyslexia often present unique challenges related to cognition, academic achievement, social interaction, and executive function [4] – skills that are critical for success in STEM fields.

The increasing emphasis on broadening participation in STEM, particularly at the K-12 level [5], presents a clear need for educational interventions that address the diverse learning needs of IWD. To this end, the *Gaming 4 Good (G4G)* project responds to this need by leveraging video game design as a teaching tool, which provides a dynamic, hands-on, and informal learning environment for IWD to engage with STEM concepts. This approach aims to move beyond traditional programming-heavy instruction, which can often present challenges for IWD due to difficulties with executive functioning and sustained attention [6]. Instead, the *G4G* curriculum emphasizes computational thinking (CT) practices through video game design, offering a creative and interactive pathway to STEM learning. Recognizing the diversity of experiences among IWD, the project adopts a transdiagnostic approach, focusing on shared challenges and opportunities rather than isolated diagnoses [4]. This approach recognizes that many neurodevelopmental disabilities share overlapping traits and barriers, thus allowing *G4G* to create inclusive and flexible learning environments for all learners.

This paper discusses the *G4G* project, a work-in-progress that is currently at the initial curriculum design stage. Preliminary data collection has not yet begun; however, ongoing co-design efforts with key contributors have informed the development of the curriculum framework. Hence, the purpose of this paper is to present the conceptual and methodological foundations of the project, outline its transdiagnostic approach, and highlight its potential to enhance accessibility and engagement in STEM education for IWD.

2 Literature Review

2.1 Transdiagnostic Approach to Learning

A transdiagnostic approach recognizes the shared challenges and experiences of IWD, allowing for more inclusive and adaptable interventions that transcend specific diagnoses [4]. This multidimensional approach considers a range of behavioral, neurocognitive, learning performance, and psychophysiological measures [7], ensuring the curriculum is sensitive to learner needs and strengths [8]. This framework may be effective for neurodiverse learners with overlapping traits from different conditions, such as ADHD, autism, and dyslexia.

Research suggests that a transdiagnostic approach can lead to more effective interventions and support systems for IWD that can better address the barriers that influence their engagement and achievement gains in STEM curricula [9]. The focus on commonalities rather than differences can enable instructors to design curricula and design learning environments that are adaptable to the diverse experiences of IWD, thereby enhancing accessibility and engagement in the classroom [4]. The *G4G* project applies this approach by using video game design to create flexible, learner-centered experiences that address the shared experiences of IWD across different neurodevelopment conditions. By focusing on common cognitive and learning processes rather than specific diagnoses, *G4G* promotes an inclusive environment that adapts to the needs of each learner, thereby enhancing their engagement and success in STEM learning.

2.2 Game-Based Learning (GBL) & Informal STEM Learning

Game-based learning (GBL) integrates instructional goals into game design to create a learning experience that is both engaging and educational [10]. This approach combines meaningful learning with enjoyment [11, 12]. Research has demonstrated that GBL is well-suited for IWD by providing a more accessible and flexible alternative to traditional learning methods [13]. By incorporating interactive elements, GBL supports the development of various skills, including visual, listening, reading, writing, social, and communication abilities, thereby making learning more engaging and customized to diverse learning needs [14].

Best practices in GBL emphasize fostering relatedness, competence, and autonomy to maintain sustained motivation and engagement [15]. When applied in STEM education, GBL has been shown to improve students' cognitive outcomes, enhance motivation, and positively influence behavior [16]. GBL also encourages collaboration and problem-solving skills [17], which are crucial for success in STEM fields. Research suggests that GBL can significantly improve students' scientific knowledge and competencies across all educational levels by engaging them in scientific enquiry activities, such as assessments and modeling [18].

Building on the benefits of GBL, *G4G* leverages digital game-based learning (DGBL) to create an inclusive curriculum that fosters CT and STEM engagement. Rather than focusing solely on playing video games, this project emphasizes video game design – a more powerful tool for developing CT skills and STEM learning [19]. Game design provides opportunities to engage in iterative problem-solving, debugging, and data analysis – all key components of CT [20]. Through game creation, IWD can apply STEM concepts in a hands-on, collaborative environment to develop skills like hypothesis testing, and data practices, thus preparing them for unconventional STEM careers in areas like computer science, game design, and instructional design.

In addition, *G4G* is situated within informal learning programs, such as after-school programs, makerspaces, and community centers. These settings remove the high-stakes pressure often associated with formal classrooms, and they have been shown to foster positive STEM attitudes and skills in IWD [21]. Their low-pressure, exploratory nature encourages collaboration, experimentation, and creative engagement with STEM concepts, which are essential for building both competence and confidence in these fields [22–24]. A key feature of *G4G*'s informal learning model is the use of an extended game jam format. Traditional game jams – collaborative, fast-paced events where participants work together to design and prototype games over a short period of time – offer a dynamic way to engage in CT skills and STEM concepts [25, 26]. However, the intensity and brevity of these events can pose challenges for IWD, including difficulties with sustained attention and fatigue. *G4G* adapts this model by extending the game jam over several weeks, giving participants time to work at their own pace while receiving continuous support from mentors and peers. This extended format promotes incremental learning and reduces cognitive overload, giving IWD the opportunity to develop their knowledge and skills in a more supportive, manageable environment.

2.3 Barriers in STEM for Individuals with Disabilities (IWD)

STEM education can present significant challenges for IWD, including both cognitive barriers and systemic discrimination. Traditional STEM education heavily relies on abstract concepts and problem-solving [2]. Computational Thinking (CT), a core component of STEM education, consists of using principles of computer science to solve problems, design systems, and understand human behavior [27]. While CT is considered a critical 21st century problem-solving skill [28] and a fundamental part of science and engineering practices [29], it is typically taught through programming exercises that demand high levels of executive functioning – such as sustained attention, organization, and problem-solving – which can overwhelm neurodivergent learners, leading to frustration, cognitive load, and ultimately disengagement [6].

Despite the growing importance of CT in STEM, it has traditionally received less emphasis for IWD [30]. Integrating CT into formal education has proven difficult, and there is even less understanding of how to effectively teach these skills in informal learning environments, especially for IWD [31]. To address these barriers, *G4G* utilizes Game Builder Garage (GBG), a platform that reduces cognitive load by shifting the focus from traditional text-based programming to more intuitive, visual game design processes. The comprehensive tutorials and interactive interface make the learning experience more accessible to IWD, allowing them to focus on problem-solving and game design rather than the technical intricacies of programming. By integrating data practices – collecting, analyzing, and interpreting data – into the curriculum, *G4G* shifts the focus from abstract programming tasks to real-world problem-solving. This approach creates more inclusive learning experiences that cater to diverse learning needs and help learners develop critical thinking skills [32].

In addition to cognitive challenges, systemic discrimination further impedes IWD from pursuing STEM fields. Many IWD face lower expectations from educators and peers [33], as well as a lack of mentorship and institutional support [2], which can hinder the development of a positive STEM identity – a key factor in sustaining long-term engagement and success in STEM fields [34, 35]. *G4G* addresses these challenges by creating inclusive, low-stakes learning environments where IWD can participate in extended game jams. These informal, collaborative, hand-on experiences allow them to explore STEM concepts and build CT skills in a supportive setting [23, 35]. The collaborative nature of the game jams fosters key elements crucial for STEM identity development, such as supportive relationships, sense of belonging, and personal agency [36]. *G4G* helps foster confidence to empower learners to view themselves as capable problem-solvers and creators within STEM. This reinforcement of a positive STEM identity is supported by research indicating that informal STEM activities can significantly improve students' perceptions of STEM careers, increase their interest in these fields, and improve their confidence to succeed within them [37–39, 24]. By offering accessible tools, a tailored curriculum, and a supportive environment, *G4G* enhances both the development of CT skills and helps overcome the barriers that have traditionally limited IWD’s participation in STEM.

3 Aims of this Project and Study

This paper aims to advance CT and positive attitudes and interest towards STEM among IWD by designing and implementing an accessible, inclusive game development curriculum. *G4G* is grounded in three principles: 1) *Accessibility* – adopting a transdiagnostic approach that emphasizes neurodiversity and utilizes learner-centered design strategies, 2) *Informal Learning* – situating learning in non-traditional environments like after-school environments, 3) *Computational Thinking Practices* – focusing on digital game-based learning and the integration of data practices within a CT framework. The team has formulated the following research questions:

- (RQ1) How can a curriculum be designed to support development of CT for IWD for deployment in informal STEM learning environments?
- (RQ2) How do key contributors (e.g., IWD, caregivers, experts) perceive the accessibility and ease-of-use of the curriculum and game development tools, and what improvements are needed?
- (RQ3) What is the influence of the *G4G* learning experience on perceptions towards STEM?
- (RQ4) What is the influence of the *G4G* learning experience on computational thinking skills?

4 Research Methods

This project employs a Learning Experience Design (LXD) – a human-centric, theoretically-grounded, and socio-culturally sensitive approach to learning design, informed by user experience design methods [40]. The project goals are to: 1) iteratively design, develop, implement, and evaluate *G4G* in collaboration with IWD, their caregivers, and subject matter experts and 2) investigate the influence of *G4G* on participants' CT skills and attitudes towards STEM over time. The study is divided into three phases. Phase 1 focuses on a highly iterative design process to inform *G4G's* development, ensuring it meets IWD learning needs based on continuous feedback. This phase includes engaging with community members and conducting needs assessments. Phase 2 involves the iterative design of the *G4G* curriculum, development of digital learning assets, and a single-pilot test in informal learning environments to assess usability and engagement. Phase 3 focuses on refining and field-testing the curriculum through iterative evaluations of alpha and beta versions, finalizing the design, and training key contributors for sustained implementation and educational impact.

To assess outcomes, we selected validated measures, such as the Computational Thinking Skills Scale (CTSS) and the S-STEM survey to evaluate attitudes towards STEM and CT Skills. These tools were chosen for their alignment with the project's goals of fostering CT and STEM engagement.

4.1 Materials: G4G Curriculum

The *G4G* curriculum consists of eight core modules, progressively introducing key CT concepts through video game design. The activities emphasize CT practices, such as data manipulation, modeling and simulation, and systems thinking [20]. By integrating these concepts into game development, *G4G* offers an authentic and engaging context for applying CT skills. The curriculum is structured around a series of extended game jams conducted in informal learning settings to enable learners to confidentially develop their skills incrementally, with continuous peer feedback and support. The Game Builder Garage platform serves as the primary tool for these activities by providing an accessible, visual programming interface that reduces the cognitive load typically associated with traditional programming, making it ideal for learners with neurodevelopmental conditions [6].

4.2 Participants

The *G4G* project will target middle school students with neurodevelopmental conditions, such as autism, ASD, and ADHD, to foster early STEM engagement. Early exposure to STEM is vital for developing positive attitudes and interests, particularly for underrepresented groups [41]. The team aims to reach a minimum of 200 IWD across Missouri and Georgia, using partnerships with local community organizations, schools, after-school programs, and summer camps to ensure a robust sampling framework.

4.3 Data Sources

To investigate the research questions, this study will employ both qualitative and quantitative research methods.

Focus Groups & Cognitive Interviews. Focus groups consisting of 3-4 IWD participants from each site will provide qualitative insights on their learning experiences with the *G4G* curriculum. A trained moderator will lead each session, which will last about 60 minutes and be audio-recorded for transcription and analysis. The goal is to explore the participants' experiences in the game jams, engagement with CT concepts, and processes of data collection and analysis during game design. These focus groups will help identify any challenges learners face during the game jam process and highlight areas for improvement in the curriculum design.

Surveys: Pre- and post-intervention surveys will be used to assess changes in participants' perceptions towards STEM and CT skills. More specifically, Computational Thinking Skills Scale (CTSS) [42], CT Self-Efficacy Scale [43], and STEM opinions survey (S-STEM Survey) [44] will be utilized. Because most prior CT research has focused on evaluating neurotypical students, validated assessment tools for IWD are lacking.

Usability Testing. To evaluate the accessibility and effectiveness of the *G4G* curriculum, tasked-based usability testing will be conducted. Learners are observed as they engage in specific game development tasks, and their interactions with the tools are analyzed to identify any barriers to participation. Sessions will be video recorded using a semi-structured think aloud protocol for evaluation of the participants' perceptions and decision-making processes. The Computer System Usability Questionnaire (CSUQ) will be used to quantitatively examine the usability of the intervention, where participants will rate their experience with 7-point Likert-based questions. The usability data will be analyzed using a combination of structural, concept, and emotion coding [45].

***G4G* Observations**. Observations will be documented using a semi-structured protocol adapted from the Electronic Quality of Inquiry Protocol (EQUIP) [46]. This protocol includes qualitative descriptive and quantitative sections addressing instruction, discourse, curriculum, and assessment. It will focus on participants' engagement with data collection, design processes, the assistance they seek, conceptual and technological challenges encountered, and how they resolve these challenges. Video and audio recordings from *G4G* activities will be analyzed to identify changes in learners' CT skills and attitudes towards STEM.

Project Artifacts. Similar to studies that have used portfolios to measure learner engagement with CT practices [47], the research team will collect participant artifacts at the individual and team level. Project artifacts, such as game design documents, prototype games, and feedback from playtesting sessions will be collected and analyzed to assess the development of learners' CT skills and the quality of their game designs over time.

5 Next Steps & Community Engagement

To ensure the successful implementation of the *G4G* project and to refine the curriculum, the research team is actively building community partnerships and gathering input from key contributors. The team has initiated outreach efforts within the Columbia-Missouri public and Athens Georgia school system, collaborating with special education teachers and facilitators who bring valuable expertise in supporting neurodiverse learners. These partnerships have connected the team with a broader network of collaborators, who are instrumental in shaping the logistical planning of *G4G.* The team is currently meeting with partner sites to discuss hosting *G4G* sessions and to address logistical considerations, such as scheduling and technology access.

Next steps include conducting focus groups with key contributors to tailor the *G4G* curriculum to the diverse learning needs and strengths of neurodiverse middle school students. These discussions will focus on how to design informal learning environments that effectively support these learners, helping to identify both challenges and opportunities. The insights gained will ensure *G4G* is both accessible and engaging for learners.

In alignment with the learner-centered co-design approach, the team will also begin interviewing neurodiverse learners and their caregivers to better understand their unique needs and potential barriers in STEM learning. Parents will provide insights into the accommodations their children require, while input from the students will directly influence the curriculum's design and development. Designing *G4G* with the input of IWD is crucial. Intentional design decisions ensure that the learning experience is accessible and allow learners to engage meaningfully with educational material, thereby potentially improving comprehension and retention [48]. By including educators, parents, and students in the co-design process, the team is ensuring that the *G4G* curriculum is responsive to the real-world needs of neurodiverse learners. The feedback gathered will guide the iterative development of *G4G*, enabling the team to create an inclusive video game design curriculum that fosters both STEM engagement and CT among IWD.

6 Discussion & Conclusion

The *G4G* curriculum presents a novel and inclusive approach to making STEM education more accessible for IWD through DGBL. By leveraging video game design to teach CT, *G4G* creates an engaging, hands-on learning environment that focuses on the shared experiences of neurodiverse learners [4], making the learning experience both inclusive and adaptable. By situating the program within informal learning environments, *G4G* provides learners the freedom to explore, collaborate, and develop their CT skills in a low-stakes setting [22–24]. The use of extended game jams allows for incremental learning, which reduces cognitive overload and provides continuous feedback, making the curriculum more accommodating to the needs of IWD. Collaboration with community partners, such as special education teachers, caregivers, and the students themselves, is crucial to the project's success. By involving key contributors in the co-design process, *G4G* ensures that the curriculum is not only accessible but also relevant to the real-world needs of IWD. This participatory approach adheres to best practices in inclusive design, where feedback from the target audience informs the design and ongoing refinement of educational interventions [49]. As the project progresses, the team will focus on collecting qualitative insights through focus groups and interviews to better understand the specific needs, preferences, and challenges neurodiverse learners experience in STEM environments.

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