Pythagorean Pixels: Enhancing STEM Relevance in Higher Education through *Terraria*

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HONRH 2034: Special Topics in Honors

Dr. Roger Chambers

December 12, 2025

Abstract

This study examines various classroom-taught concepts from higher STEM education coursework in the underlying mechanics of the 2D sandbox *Terraria* (2011), with the aim of improving the perceived relevance of higher STEM education. Although existing scholarly work has explored the perception of STEM coursework relevance in higher education, little has accounted for long-term effects of relevance perception and students' backgrounds in video games and gaming experiences. Examining the scholarly work surrounding STEM higher education and how its perceived relevance relates to student motivation within the classroom, this research explores *Terraria* as a case study for demonstrating how complex STEM concepts naturally emerge within forms of student entertainment outside of the classroom. *Terraria*'s vast range of complex mechanics, ranging from projectile motion to procedural world generation, reveals its authentic representation of abstract STEM concepts, such as vector valued functions and various noise algorithms. These results suggest that such connections may help students recognize the practical role of STEM content outside of a formal academic setting, increasing motivation, interest, and conceptual understanding. Future research could examine additional higher education STEM concepts in other commercial games, explore different academic age groups, and consider how cultural, socioeconomic, and governmental factors influence both media use and educational relevance.

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Over the years, digital media has become one of the most influential forces in modern culture, shaping societal interactions on a global scale. Among these forms of media, video games in particular serve not only as strong forms of entertainment but also as complex systems filled with mathematical, computational, and logical structures. Despite this, video games are rarely acknowledged within higher education as strong examples of academic concepts and are instead often framed as distractions from learning and oppositions to education. By exploring concepts from STEM higher education coursework through video game mechanics and using qualitative content analysis, this research aims to improve the perceived relevance of STEM higher education and student motivation in the classroom. There are a large number of concepts surrounding mathematics and computer science that can be explored in a majority of both 2D and 3D games. Conveniently, the modern 2D games industry provides simplicity in uncovering these principles by only demanding two dimensions. By focusing on a single 2D game, these topics can be explored in-depth and in a narrower, more isolated context. Released in May of 2011, *Terraria* is a 2D action-adventure sandbox with distinct mechanics that simulate a variety of prominent calculus and computer science concepts. Through identifying and analyzing these principles, the game will serve as a case study of how educators can promote creativity, curiosity, and engagement within mathematics and computer science classrooms.

Literature Review

Conveniently, there is an abundance of scholarly work surrounding STEM higher education and how its perceived relevance relates to student motivation within the classroom. For starters, in an article that explores game-based learning, authors Zhao et al. (2022) discuss the demand for skills in the ICT (Information and Communication Technology) sector with regard to computer-programming course enrollment and dropout rates in higher education in the UK. These scholars challenge traditional teaching methods in programming coursework by exploring the employability of flipped classroom and game-based learning approaches. By explaining how these recommendations have been used to improve hands-on educational experiences in complex programming coursework, this article is key in analyzing how *Terraria*, a hands-on method of comparison, represents abstract STEM concepts. Additionally, authors Johansen et al. (2023) cover the correlation between content relevance and motivation within higher education STEM students through the use of self-determination theory (SDT). The authors found that making coursework content and activities more relevant for students contributes to an increase in motivation, vitality, and effort in the classroom. Thus, exploring STEM concepts in higher education through *Terraria*'s mechanics is sure to improve the perceived relevance of STEM coursework.

Despite the rich insight into this particular avenue of research, both groups of authors have their own set of shortcomings that highlight the gap in the greater scholarly context of this field. First off, Zhao et al.'s studies only measure engagement and retention over a short period of time through a single session. The article does not explore how the game-based approach influences long-term conceptual understanding in STEM learning. The study also overlooks non-educational games for context in which academic concepts naturally exist, failing to connect content with students' existing, and often thorough, gaming experiences. Moreover, the work maintains a narrow focus on introductory programming coursework because of its high abstraction and complexity. However, it doesn't connect themes to broader STEM disciplines, like calculus, to explore how methods may differ when comparing different courses. Similarly, authors Johansen et al. do not investigate the interaction across varying STEM disciplines, influences on long-term retention and applied understanding, or students' preexisting gaming experiences to measure relevance. On another note, the authors fail to explore interactive systems like games or virtual environments, and instead rely on curricular and text-based problems for relevant context.

In summary, authors Zhao et al. and Johansen et al. separately provide meaningful context surrounding the perception of STEM coursework relevance in higher education. Their work serves as foundational research in supporting how *Terraria* represents and improves the relevance of complex calculus and computer science concepts. However, the authors fail to explore the long-term effects of relevance perception and the target groups' backgrounds in video games and gaming experiences. Nonetheless, both works are crucial in uncovering the role of perceived relevance in STEM higher education and for framing the broader scholarly context.

Educational & Industrial Context

For some background, the global education sector contains vast economic, social, and technological significance. The global education market, including early childhood education, K-12, post-secondary education, and workforce training, is valued at around USD $7.6 trillion, and is estimated to reach almost USD $10 trillion after the year 2030 (HolonIQ, 2025). Moreover, K-12 and post-secondary education collectively make up around 80 percent of the total market value (HolonIQ, 2025). This represents the scale of worldwide education and provides insight into how formal learning may influence global economic trends. The projected growth of this market reflects the rising demand for access to global higher education, which highlights its significance in modern advancement. Within higher education, the fields surrounding STEM (science, technology, engineering, mathematics) play a central role in both institutional and industrial development, which is backed by industry metrics. For example, the information and communication technology (ICT) sector within countries under the Organisation for Economic Co-operation and Development (OECD) grew at an average rate of 7.6 percent in 2023 (OECD, 2024). This growth reflects an increased demand for skills surrounding computation and algorithms, rooted in foundational disciplines like calculus and computer science. Thus, STEM higher education is not only a curricular component but also a domain for workforce and industry advancement. As a whole, this data emphasizes the significance of the perceived relevance of STEM higher education coursework resulting from the vast scale of global education, global higher ed, and technological development. If students perceive STEM coursework as irrelevant or disconnected from real-world applications, this misalignment will lead to a decline not only in education but in the structure of broader economic and industrial development.

Video Games

Since it has been around for quite some time, the video game industry has grown into one of the largest and most influential components of global entertainment and culture. In the United States alone, around 61 percent of people report playing video games at least an hour per week, with an average player age of 36 in 2024 (Entertainment Software Association, 2024). This data reveals that the gaming domain is not limited to children or young adults, but rather spans a broad demographic that makes it relevant for many in higher education. Within the broader industry of video games, 2D games (games in two dimensions) represent a distinct sub-category. Generally, two-dimensional games are easier to develop than those in three dimensions, primarily due to the simplicity of assets, less complex programming, and lower production costs. Therefore, this study will focus on a 2D sandbox game in order to isolate and simplify the connection between game mechanics and calculus and computer science mechanics. On another note, it's worth mentioning that despite the prominence of video games in everyday life, they are frequently viewed as an opposition to education (e.g., a student playing online games instead of doing their homework or studying). By exploring how game systems can connect students' entertainment with formal instruction, this study seeks to shift video games from an opponent of learning to a vehicle of relevance and significance in STEM education.

Case Study: *Terraria*

Of course, with the plethora of video games available, at least one of them will inevitably be useful in representing complex STEM concepts from higher education. Developed by Re-Logic and published by Re-Logic and 505 Games in 2011, *Terraria* is a 2D action-adventure sandbox and platformer video game. Players are meant to explore a vast world, gather resources, upgrade gear, and fight enemies and bosses, with a variety of additional systems that promote creativity and experimentation. As of May 2025, *Terraria* has sold over 64 million copies (Murphy, 2025), making it one of the top ten best-selling video games of all time (Sirani, 2025). Additionally, the game has a global playerbase, with the U.S. and China making up almost 40 percent of the active player population, followed by nearly 20 percent of active players from Russia, Germany, and the UK (Raijin, 2025). This reveals the game's broad demographic, tying into its potential global influence surrounding STEM higher ed. Furthermore, *Terraria* has contributed to the advancement of the 2D sandbox genre, inspiring Japanese title *Airship Q* (2015), whose developers noted the game as a major influence (Eugene, 2014). All things considered, *Terraria* is a prominent, influential game that encompasses several calculus and computer science mechanics, which can be explored in the context of STEM higher education coursework.

First off, *Terraria*'s wide range of movement mechanics fundamentally requires the implementation of vector-valued functions. All forms of player motion in the game are stored internally as vectors, which define direction and magnitude at any given moment. These vectors are constantly being recalculated by the game's engine and adjusted accordingly based on a variety of gameplay factors. Accessories, environmental influences, and other external factors all play a role in the player's velocity and acceleration, helping create a simulation of vector interactions. For example, Hermes Boots is an accessory that increases the player's maximum running speed by scaling the magnitude of the velocity vector. Conversely, environmental factors like high-speed winds in sandstorms or blizzards create opposing forces on that same velocity vector, reducing the player's overall movement speed. Even subtle mechanics like water resistance or friction across different blocks contribute to a player's movement. Collectively, these interactions make *Terraria* a strong representation of vector operations, concepts students usually encounter only through static diagrams or equations in textbooks. In a broader academic context, the math behind these mechanics directly ties into the material taught in undergraduate calculus. Vector-valued functions, motion in space, and force interactions are central learning objectives of multivariable calculus courses, particularly in STEM majors like engineering, physics, and computer science. For instance, multivariable calculus courses commonly taught at universities across the United States introduce students to vector-valued functions and their applications, including topics such as displacement, velocity, and acceleration. *Terraria*'s movement system models these concepts beautifully, providing students with an authentic experience in the same concepts they can find in a more formal educational setting.

Another prominent mechanic in *Terraria* that strongly reflects foundational calculus concepts is the use of bows and other ranged weapons, operating under simulated projectile motion. Most standard projectiles in the game follow a curved trajectory influenced by gravity, launch angle, and initial velocity. This behavior closely models parabolic paths explored in multivariable calculus, relating to projectile motion. When a player fires a bow, the arrow's path is determined by its initial velocity, which is then influenced by gravity, and sometimes other factors in the game. In higher education, these patterns tie directly into parametric equations and vector-valued motion. More specifically, advanced calculus coursework explores how position, velocity, and acceleration interact to contribute to projectile motion. *Terraria*'s ranged combat system provides an intuitive example of these principles, which offers students an interactive counterpart to the variety of material they encounter in formal STEM coursework.

Additionally, *Terraria*'s non-player character (NPC) movement and enemy behavior provide another compelling example of STEM concepts embedded directly into gameplay, particularly through the use of pathfinding algorithms. Whenever an enemy attempts to attack a player, like a zombie navigating terrain or a flying creature adjusting its flight path, the game relies on algorithmic logic to determine the most efficient path of travel from one point to another. In this case, among others, *Terraria* reflects core ideas from graph theory. Each tile in the game's engine functions as a node, and each possible path between those tiles forms the connections, known as edges, of a graph. In determining which of these edges are most viable, the game employs computer science algorithms like Dijkstra's algorithm and A*. These are commonly known and widely used algorithms that attempt to find the most efficient path, considering a multitude of traversal cases. Although enemies appear to be conscious of their environment and surroundings, their behavior fundamentally ties back to these complex algorithms. These concepts are typically explored in mathematics and computer science classes, such as discrete mathematics or algorithms and data structures. For example, many undergraduate computer science programs include courses on data structures and algorithms that place an emphasis on shortest-path techniques such as Dijkstra's algorithm. *Terraria*'s AI and pathfinding systems represent these principles in an authentic way, allowing players to experience fundamental elements of algorithms and data structures in an entertaining light on top of a formal academic setting.

Furthermore, *Terraria*'s world generation system provides yet another example of abstract STEM concepts serving as the foundation for gameplay, most notably through the use of what's known as procedural generation. This is a method utilized by the game developers through the game engine to automate the process of world creation, often involving the use of algorithms and noise functions rather than tedious, tile-by-tile design. Each time a new world is created, the game constructs mountains, bodies of water, biomes, and various underground layers using these noise patterns. Specifically, *Terraria* implements Perlin noise, a gradient noise function used in computer graphics to simulate smooth, natural variation. Thus, a freshly generated world isn't constructed so randomly, which would look chaotic and choppy, but instead follows continuous transitions between values, allowing players to feel immersed in a world that still reigns beautiful in its unpredictability. This entire process closely follows what students learn when studying procedural generation and Perlin noise in different computer science courses. For instance, advanced undergraduate courses in game development often introduce students to the principles and practices of game design and programming, including the technical foundations behind systems like procedural generation. Behind the scenes, *Terraria*'s worldbuilding process provides an interactive example of these principles, allowing students to understand how gradient noise can be used to create detailed and complex environments.

Finally, *Terraria*'s enemy spawn rates and item drop systems provide yet another example of how abstract STEM concepts can be explored through gameplay, primarily through a lens of probability and statistical modeling. The underlying logic behind these mechanics closely resembles a Poisson process. Enemies spawn independently over time, with each spawn event maintaining a constant probability and not directly influencing the next, which aligns with the Poisson concept of random events occurring at a steady rate. This framework also applies to item drops since the likelihood of receiving items of varying rarity from enemies follows a predictable probability distribution that students analyze in statistics coursework. Moreover, even ore spawn rates in a newly generated world exhibit a similar pattern, where ore clusters in a given area can be approximated by applying Poisson principles. These concepts appear in higher education coursework like discrete mathematics, probability, statistics, and stochastic processes. For example, probability courses designed for computer science majors frequently cover the Poisson distribution in depth, examining how it models random, independent events across time and space. *Terraria*'s spawn rates and drop systems provide players and students with an intuitive view of these principles in action, outside of a formal academic setting, which offers a perspective on a widely used statistical model in STEM coursework.

Discussion & Conclusion

With these findings, it is evident that there are rich applications of calculus and computer science concepts in *Terraria*, all of which can be found in commonly taught college courses. These discoveries reveal that STEM higher education is not confined to textbook learning but is rather embedded in the virtual environments students indulge in for entertainment outside of the classroom. This offers a new perspective on how abstract STEM concepts come to life in digital worlds heavily tied to modern culture, which provides educators with an opportunity to reframe the relevance of these concepts, ensuring students will strengthen their understanding in coursework surrounding this field.

Beyond their significance, these insights carry several notable implications that are tied to global deviations. For starters, this research does not account for a wide range of differences between cultures on a global scale, as well as socioeconomic conditions and bureaucratic operations. Although the video game industry is large, as a form of entertainment, the popularity of video games varies greatly across different countries. Socioeconomic differences also play a role, as not every nation has access to video games, higher education, or even the most basic forms of early education. Moreover, government operations may also hinder access to video games, since many different countries place various bans.

For future research, it would be meaningful to explore additional STEM concepts from higher education in other games like *Terraria*. Given the variety of 2D and 3D games, there is an abundance of resourceful systems that simulate a wide range of complex concepts seen in higher education STEM coursework. Additionally, scholars could take this approach and apply it in the context of other academic age groups, such as primary and secondary school students, as there is a significant difference in learning patterns. Moreover, with this scale considered, it would be worth looking into concepts from other disciplines in video games to increase content relevance across a wide range of fields. Finally, researchers could narrow similar studies down to more specific geographical regions to account for cultural, socioeconomic, and governmental differences that may, in one way or another, affect forms of media and higher education.

Overall, *Terraria*'s movement mechanics, projectile systems, NPC pathfinding, drop rates, and procedural world generation systems all tie into complex concepts seen in STEM higher education coursework. These connections shed light on the idea that abstract principles are not confined to formal classroom education but are also seen in forms of media and entertainment that students interact with on a daily basis, all around the world. By acknowledging these ideas, educators can better position STEM content as meaningful and relevant, as they're heavily grounded in students' everyday experiences. This shift doesn't require existing curricula to be reframed, but it requires the recognition of opportunities that already exist. For students around the world to value what they learn, the education sector must first bridge the connections that have been in front of them all along.

References

Entertainment Software Association. (2024). *2024 essential facts about the U.S. video game industry*. Entertainment Software Association. https://www.theesa.com/resources/essential-facts-about-the-us-video-game-industry/2024-data/

Eugene. (2014, January 26). *Cygames investing 70 million yen in japanese indie darling Airship Q*. Siliconera. https://www.siliconera.com/cygames-investing-70-million-yen-japanese-indie-darling-airship-q/

HolonIQ. (2025, February 17). *The size & shape of the global education market*. https://www.holoniq.com/notes/the-size-shape-of-the-global-education-market

Johansen, M. O., Eliassen, S., & Jeno, L. M. (2023). "Why is this relevant for me?": Increasing content relevance enhances student motivation and vitality. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1184804

Murphy, T. (2025, May 16). *Terraria Turns Fourteen!* Terraria Community Forums. https://forums.terraria.org/index.php?threads/terraria-turns-fourteen.143140/

OECD. (2024, May 14). *Growth of digital economy outperforms overall growth across OECD*. OECD. https://www.oecd.org/en/about/news/press-releases/2024/05/growth-of-digital-economy-outperforms-overall-growth-across-oecd.html

Raijin. (2025, November 12). *Terraria*. https://raijin.gg/app/105600/Terraria/player-count

Sirani, J. (2025, February 18). *The 10 best-selling video games of all time*. IGN. https://www.ign.com/articles/best-selling-video-games-of-all-time-grand-theft-auto-minecraft-tetris

Zhao, D., Muntean, C. H., Chis, A. E., Rozinaj, G., & Muntean, G.-M. (2022). Game-Based Learning: Enhancing Student Experience, Knowledge Gain, and Usability in Higher Education Programming Courses. *IEEE Transactions on Education*, *65*(4), 1–12. https://doi.org/10.1109/te.2021.3136914