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

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Abstract

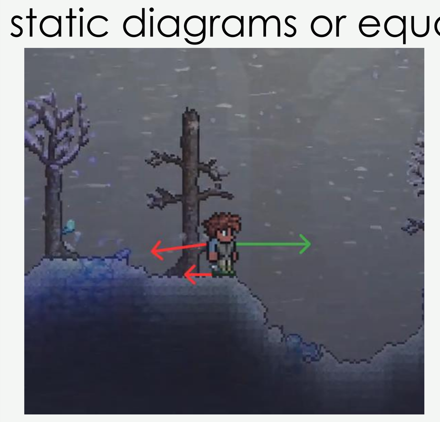
This study examines various classroom-taught concepts from higher STEM education coursework in the underlying mechanics of the 2D sandbox *Terraria* (2011), with the aim of improving the perceived relevance of higher STEM education. Although existing scholarly work has explored the perception of STEM 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.

Methodology & 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. 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. 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. 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.

Case Study: *Terraria*

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. Collectively, these interactions make *Terraria* a strong representation of vector operations, concepts students usually encounter only through static diagrams or equations in textbooks.



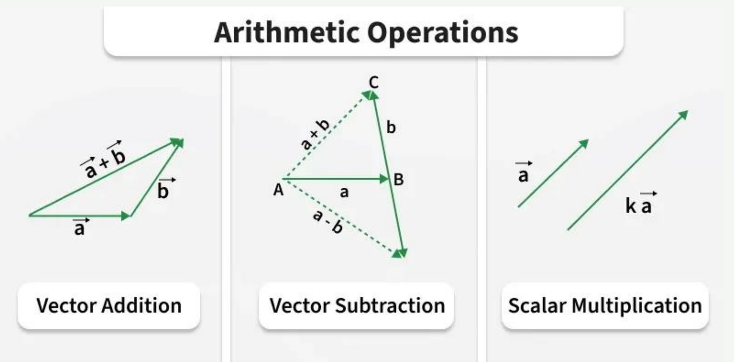


Figure 1. *Player movement affected by snowstorm winds*. YouTube (isloths), 2024. **Figure 2.** *Vector operations in calculus*. GeeksforGeeks, 2023.

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.

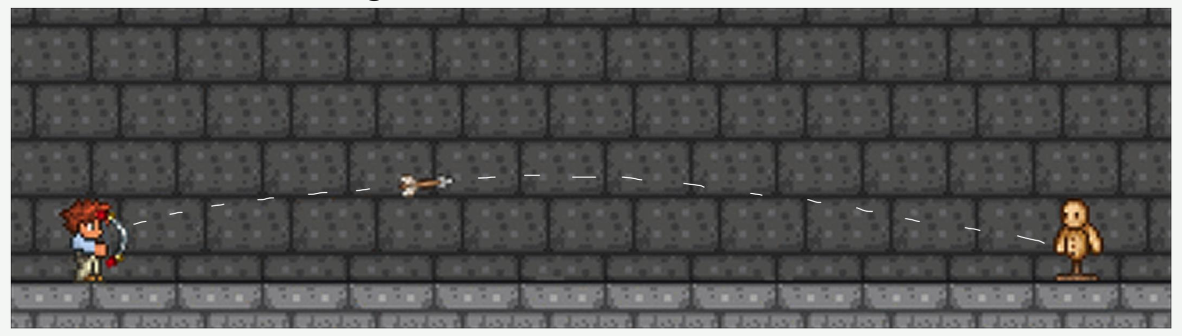
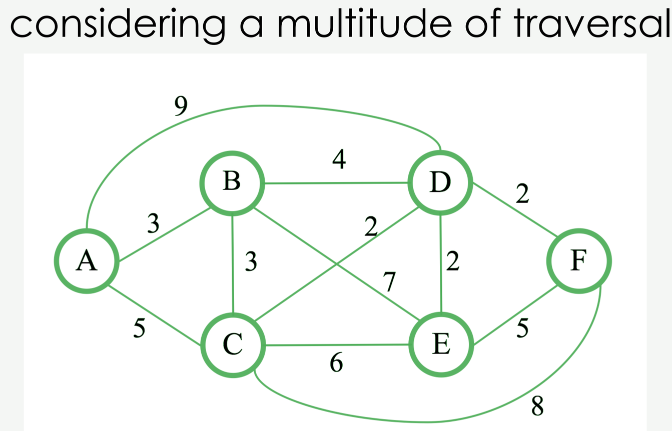


Figure 3. *Player firing a bow in Terraria*. Terraria Wiki (Fandom), 2024.

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. 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.



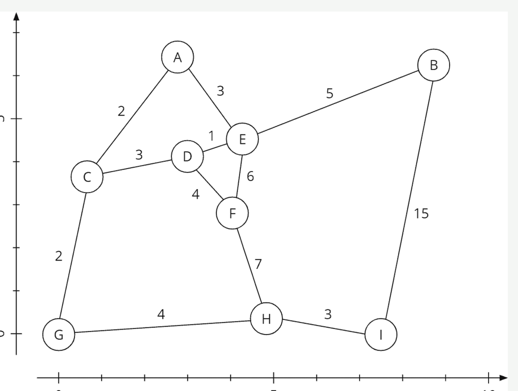
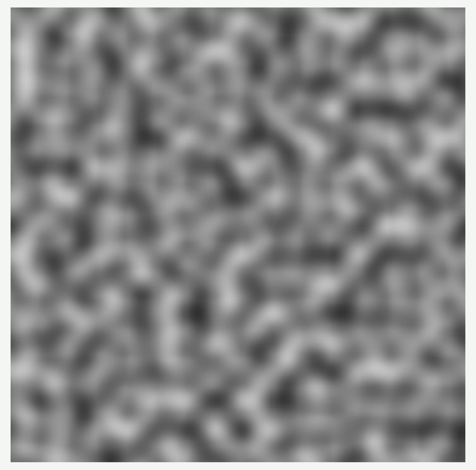


Figure 4. *Visualization of Dijkstra's shortest-path algorithm*. StackOverflow, 2023. **Figure 5.** *Visualization of A* algorithm*. HappyCoders.

Case Study: *Terraria* (cont.)

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. This entire process closely follows what students learn in different computer science courses.



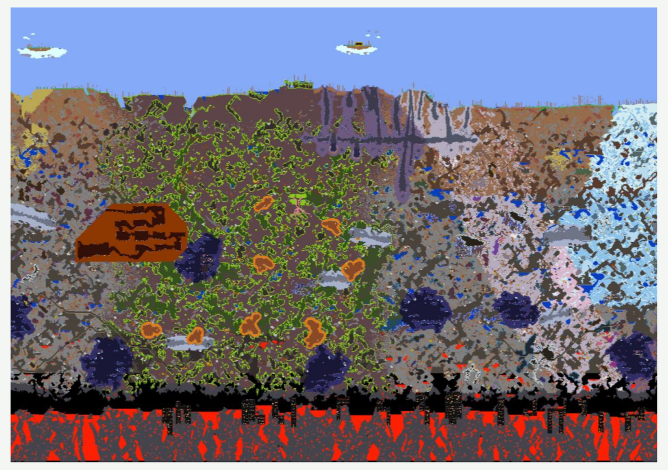


Figure 6. *Perlin noise pattern*. Unity Documentation, 2024. **Figure 7.** *Example of full Terraria world structure*. Godot Engine Forum, 2023.

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 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.

Figure 8. *Enemy drop rates*. Terraria Wiki (Fandom), 2024.

$$P(X = x) = \frac{\lambda^x e^{-\lambda}}{x!}$$

where

x = 0, 1, 2, 3, ...

λ = mean number of occurrences in the interval

e = Euler's constant $\approx$ 2.71828

Figure 9. *Formula for Poisson distribution*. OnlineMathLearning.

Results & Conclusion

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. 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 extremely opportunity to reframe the relevance of these concepts, ensuring students will strengthen their understanding in coursework surrounding this field. 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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