Using Curiosity Model to Characterize Edutainment Based on Learner's Growth Rate

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Abstract. In recent years, there has been a growing interest in learning through games. However, learning through games has never been measured; thus, failed to attract many investors in this field. As such, the goal of this paper is to identify the concept of progress curves in edutainment games using the proposed "Curiosity Model" or momentumin-mind. The importance of curiosity during the progress of the game is discussed. Further, it explores the possible interpreting the physics in the real world to physics that goes in the mind during the game-play. The approach was then applied to SameGame (entertainment game) and Memrise (edutainment game) to identify the differences between the two categories of single player game. The results indicate that the curve of momentum is built up differently in edutainment games and entertainment games. Therefore, the approach used in this paper can help developers and educators increase the effectiveness of edutainment games.

Keywords: Curiosity Model, Edutainment, Entertainment, GameBased Learning, Momentum in Mind, Memrise, SameGame

1 Introduction

Playing games especially electronically is a very popular pass-time activity among adolescents and children and they seem to have a prominent role in the culture of young people [1,2]. Prensky [3] calls 'digital game-based learning' as the method which seems to be deep-rooted now among the young generations for learning. Colace et al. [4] defined edutainment beautifully by referring it as the marriage of education with entertainment. In particular they refer edutainment as a form of entertainment specifically designed to educate as well as keep the students amused by implanting entertainment such as television programs, video games, Online Multimedia tools etc. into the core lessons of education. This paper mostly concentrates on one aspect of edutainment, i.e., game based learning, though it may be extended to generalize the whole concept of edutainment. Furthermore, serious games were pointed out in many works that they succeeded in improving student motivation, increase students desire to learn and make learning more enjoyable [5].

A number of authors (e.g. Gee, 2003[6]; Malone, 1980[7]; Prensky, 2001[3]) keep up that this method of learning can be more agreeable, additionally fascinating, and, consequently, more viable than customary learning modes. and comprise possibly intense learning conditions for various reasons [8]: (a) they can bolster multi-tactile, dynamic, experiential, issue-based learning, (b) they support enactment of earlier learning given that players must utilize beforehand learned data with the end goal to

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propel, (c) they give prompt input empowering players to test speculations and gain from their activities, (d) they include open doors for self-evaluation through the systems of scoring and achieving diverse levels, and (e) they are progressively turning into social environments involving networks of players.

As mentioned earlier, as of late, different organized games, for example, massive multi-player online games, have developed, making a path for another community-oriented model for learning [9]. The players of such games get benefited from collaborating among themselves both inside the amusement condition (e.g. through networking on the web-based groups) and around it (e.g. through sharing game-related data and assets). Several researches that assessed the effect of the use of electronic games in multiple domains, for example, arithmetic, science, language, geography, and computer science, have demonstrated positive results as far as player's inspiration and learning adequacy in connection to curricular targets (e.g. Klawe, 1999[10]; Papastergiou, 2009[11]; Rosas et al., 2003[12]; Virvou, Katsionis, & Manos, 2005[13]). In game refinement theory, the uncertainty of the game outcome is described with classical physics model [14]. Game refinement measure reflects the attractiveness of a game from the viewpoint of designers. A game is enjoyable when its challenge matches with preferences and skills of a player [15]. While deficiency leads to a tiresomeness, an extreme difficulty may lead to frustration. With that, the high perceived challenge is also one of the conditions in flow theory [16], which results in a loss of self-consciousness and track of the time. In 1907, Lucinda Pearl Boggs [17] pointed out, in his paper "The Psychology of the Learning Process", four important things for learning to take place in the best way. They are (1) the attitude of the mind, (2) the contents of consciousness, (3) the form of the contents of consciousness, and (4) the structure of consciousness. It can be inferred from this, how important is the consciousness for any kind of learning. It can be a game-play or learning through games. These aspects of consciousness are what shapes a game. In practice, mass-in-mind is not always a constant but depends on various uncontrollable causes as discussed by Kananat et al. [18]. For instance, current mood and temper may affect the enjoyment of a game. Hence, the player may not have the same intuition while playing the same game. In another study by Agarwal et al. [19], a hypothesis of how Mass in the mind is related to Neuroscience is presented. It says how the connection of synapses of the player's mind is strengthened when something is revised and new connections are formed when something new is learned. However, little works have examined the impact of these types of learning games on students level of knowledge. Most of the times the gaming element is questioned. We are never sure how much gaming element is enough for an educational game. It is very important to understand the aspects and see that these games do not lead to boredom or addiction. Thus, we must understand the Physics in mind to get a clear understanding. Also, there have been arguments on multiple times about the effects of game-play on the human mind. In some cases, the game excitement is too low that it does not entice the player at all. In another scenario, the game excitement is too high that the player does not know when to stop. With that, we try to create a border between the learning curves in entertainment games and serious games. We introduce the concept of 'Momentum in Mind' which is further used to understand edutainment and entertainment in a more refined manner. We have always known the general difference between these terms but this paper gives a mathematical difference between the two using the concept of momentum.

In Section 2, we discuss the real world physics and physics in the mind and how we can extend the concept of momentum from single player game to two player game. In Section 2.3, we show the results from our simulations of finding momentum and its application to two games: SameGame and Memrise. Further in Section 3, we discuss, how these game models teach us to differentiate between edutainment and entertainment with the aid of flow theory. In our last section, we provide the conclusion to the theory and future scopes.

2 Why Momentum?

2.1 Real World Physics

Definition 1. *Momentum in Real World Physics: Momentum is a measurement of mass in motion: how much mass is in how much motion. It is usually given by the symbol p [20], as shown in Eq.*
(1).

$$\vec{p} = m \cdot \vec{v} \quad (1)$$

Where m and $\vec{v}$ stands for the mass and velocity respectively. The standard units for momentum are kg.m/s, and momentum is always a vector quantity. This implies that doubling either the mass or velocity of an object will simply double the momentum. The momentum in real-world physics is conserved.

2.2 Single player game vs. Multi-player game

A single player game, the competition is with oneself in the future as the player moves ahead in the game. It is similar to the theory of a two-player or a multiplayer game. In order to win, one player must be stronger than another. But for the game to be equally competitive, the difference between the abilities of the player should not be too much. Elo Rating System can be used to define the ability difference, however, the problem is, even though the player does not play the game for a long time (Player A), his Elo rating still remains the same. So, when Player A plays against Player B (someone who has recently achieved a high rating with constant effort), it is most likely that Player B will win. This is the reason why time is considered while calculating the progress. Most two-player games are a zero-sum game but single player games, esp., games in educational game context have a building up strategy. Though the concept of Momentum is applied for single player games in this paper, it can be extended to two-player games.

2.3 Establishment: Momentum in Mind

This paper explores the area of the momentum with respect to the games. In a game domain, the quintessential factor is the difficulty between the levels with respect to the time. It is used because the difference between two levels can signify the progress achieved and thus denotes the impact a game can have on the player's mind. Though the information with respect to any game is an Absolute value, the time is always a Relative measure of the player's ability. Since this paper refers to the mass in motion with respect of time, it is called as Momentum in Mind. This can also be called as "Curiosity model" as it denotes the progress/growth with respect to the levels.

Table 1. Correspondence between Real World physics and physics in mind

Notation	Real World Physics	Physics in mind
		Information from the level
		Time to acquire the information
p~ = m ·~v	Momentum	Momentum of the player

Based on the perception described above, the definition of the momentum in mind, or growth over a period of time by a player, is given in Definition 2.

Definition 2. *Momentum in Mind: Momentum in mind is defined as the growth rate of mind of the player while moving from one level to another acquiring a set of information from the level.*

$$\vec{p} = (\ln \frac{h}{l}) \cdot \frac{1}{t} \tag{2}$$

The time t signifies the time taken to acquire information to reach a higher level in the game. It can be measured as the difference in the levels or in the unit of time. If the time is reduced, momentum increases and vice versa. Thus, momentum is inversely proportional to time if the progress (h/l) is kept constant. Natural log is taken to define the shift between the two levels. Table 1 relates the main elements of physics in mind and the real world which contributes to momentum. **Table 2** summarizes the mathematical model of game progress using momentum.

Table 2. Momentum in Mind

Notation	Game progress model
	Game Information at higher level
	Game Information at lower level
	Time taken between the levels
$\vec{p} = \left(\ln \frac{h}{l}\right) \cdot \frac{1}{t}$	Momentum (p~) acquired

Remark 1. In this paper, it is supposed that unlike momentum in real world physics, momentum in mind is not a conserved value. Momentum in mind is conserved or not, it still requires further research and validation.

In this paper, the model is applied to the games to find the learning rate and how it varies between the games.

2.4 SameGame

SameGame is a tile-matching puzzle initially released under the name ”Chain Shot” in 1985 by Kuniaki Moribe (Morisuke). It consists of a grid composed of cells of different colors, regularly at first filled up with four or five blocks of squares put indiscriminately. Adjacent cells of the same color can be removed together. When cells are removed, the upper cells fall down, and when a column is empty the columns to the right of the empty column is moved to the left. There is a bonus of 1,000 points for removing all the cells. The objective of the game is to expel as many squares from the playing field as would be prudent. Most versions of the game give $(n-k)^2$ points for removing n tiles at once, where $k = 1$ or 2, depending on the implementation. In this case, $k = 2$ is considered since it is more usually considered. SameGame is an NP-complete puzzle [21].

The search space of different levels of the game is taken from [22] [23], as shown in **Table 3**. Nested Monte Carlo Tree Search [22] is applied in the single player game scenario. Level 2*m* and 3*m*, where *m* denotes the memorization of the best move, which in turn makes the game easier to play. Therefore, it is taken one level below the same level without memorization. Search Space is an information about the game that the player gradually obtains while moving ahead in the game. Hence, search space is considered mass in mind in order to quantify momentum (**Table 4**).

Table 3. Search space of SameGame [22] [23]

	Level 2*m*	Level 2	Level 3*m*	Level 3
Total search space	65,937	44,731	77,934	73,998

Table 4. Momentum of SameGame between the levels

Level difference	Level 2*m*-2	Level 2-3*m*	Level 3*m*-3
p~	0.388032967	0.555195541	0.051824249

2.5 Memrise

Memrise is a language learning app, whose developers claim to be using scientific learning approach in the most fun way possible. When a user learns new things or revises the previously learned lessons, the user gets experience points. User levels up as he/she gains experience points [24]. The game is examined to identify the gaming elements (points system) which are the only quantifier of the information in the application. The curiosity model is applied further to examine the momentum (**Table 5**).

Table 5. Memrise: Momentum

Level	XP	p~
1	500	0.69314718
2	1,000	0.69314718
3	2,000	0.69314718
4	4,000	0.69314718
5	8,000	0.69314718
6	16,000	0.69314718
7	32,000	0.69314718
8	64,000	0.69314718
9	128,000	0.91629073
10	320,000	0.91629073
11	800,000	0.91629073
12	2,000,000	0.91629073
13	5,000,000	0.91629073
14	12,500,000	0.91629073
15	31,250,000	1.16315081

3 Analysis and Discussion

Two graphs are plotted in order to show the differences in momentum with respect to levels in SameGame (**Figure 1**) and Memrise (**Figure 2**). These graphs give the necessary approach to separate educational games from entertainment games.

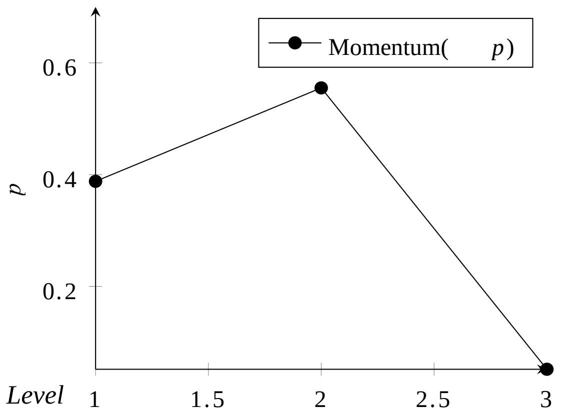

Fig.1. Momentum with respect to levels in SameGame. The figure shows the increasing momentum initially as the game progresses but then decreases.

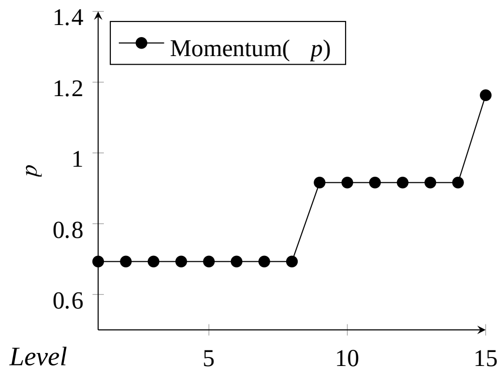

Fig.2. Momentum with respect to levels in Memrise. The figure shows the increasing momentum as the game progresses towards higher levels.

The momentum decreases subsequently in entertainment games as the game progresses, but decreases sharply after a period of time (see Figure 1). In this case, the momentum has a rising slope from the beginning, which is too high to maintain. Most entertainment games have limited information and it is usually offered in the first few stages. However, as we move further, due to the lack of information in the game, momentum decreases and is almost zero after a certain point. It is also evident from the discussion on the importance of velocity in the game progress. If the velocity is too high in the beginning, the game will not last too long, which is what happens to most entertainment games. The player does not have the feeling to be engaged after some period of time as the game has few insights now and it is mostly monotonous. It does not challenge their abilities enough. That is why most entertainment games can result in addiction if the momentum is not taken into account carefully.

Meanwhile, in educational games, the momentum periodically increase after a certain period of time, but retain at a relatively leveled rate (see Figure 2). In edutainment, the momentum needs to be maintained and the velocity must be kept low in the beginning, for the learning to be smooth and game to be entertaining. The player should get used to the learning environment first while keeping it entertaining. In such cases, momentum is required to be maintained relatively with the time, because curiosity triggers momentum by increasing the activity in the brain.

As per Dr. Mihaly's research [25], there is practically universal assumption that when there is certainly not a high connection between the challenge (the tallness of the mountain, the profundity of the plunge) and the capacity to address that difficulty, fun is something we are unquestionably not experiencing. The principle discourse (dynamic) is among 'Challenge' and 'Ability'. At the point when the challenge is more than our capacities, we wind up on edge and possibly dead. At the point when the challenge is fundamentally not as much as that of which we are commendable, we wind up exhausted and conceivably dead. He utilizes the term "optimal experience" to depict those events where we go through a feeling of elation, a profound feeling of pleasure, which we treasure for long and that turns into a milestone in our lives.

From this research, it is found that we need momentum with respect to the ability and the challenge just enough that it provides "Optimal Experience" rather than boredom or anxiety. In edutainment, momentum must be increased slowly with the levels in order for the player to get used to the learning and does not get bored with the redundant or lack of information. In entertainment, it has to be high to give player a sense of excitement, however it must be taken into account that the information about the the game should not be provided at once. There must be uncertainty in the game until the end to maintain the excitement throughout the game.

Conjecture 1. If the curve for momentum starts to fall at any period of time, the game has more gaming impact than educational impact. If the curve is always rising but too low, it has a more educational impact than gaming impact.

4 Conclusion and Future Works

This paper relates the Physics in Real Life to Physics in mind. Momentum in real life works with constant mass and varying velocity, however, Momentum in mind explains how mass in mind changes with time. Also, it attempts to define the difference between the game-progress of entertainment games and educational games yet the clear border has not been identified in this paper which is left for future work. Where entertainment games are most likely to be zero-sum, educational games are always accruing. Momentum value levels down at some point in entertainment games as opposed to edutainment when the momentum is always building up.

The theory of momentum in mind is a new concept and needs additional validation on furthermore games. The paper still leaves the scope of finding the ideal value of momentum to keep the learning process smooth. This paper presents a hypothesis from the evaluation and discussion that the momentum curve must have a lower value for a stable learning process in Edutainment. In the case of Entertainment, the ideal momentum value should be the one which allows the optimum experience without resulting in addiction.

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References

[1] Mumtaz, S.: Children's enjoyment and perception of computer use in the home and the school. Computers and Education **36**(4), 347–362 (2001) doi: 10.1016/S03601315(01)00023-9

[2] Nippold, M., Duthie, J., Larson, J.: Literacy as a leisure activity: Free-time preferences of older children and young adolescents. Language, Speech and Hearing Services in Schools **36**(2), 92–102 (2005) doi: 10.1044/01611461(2005/009)

[3] Prensky, M.: Digital Game-based Learning. Computer Entertainment **1**(1), 21–21 (2003) doi: 10.1145/950566.950596

[4] Colace, F., Santo, M.D., Pietrosanto, A., Troiano, A.: Work in Progress: Bayesian Networks for Edutainment. In: 36th Annual Conference on Frontiers in Education, pp. 13–14. IEEE, San Diego, CA, USA (2006) doi:10.1109/FIE.2006.322573

[5] Mohamed A.K., Essalmi, F., Mohamed, J.: Comparison Between Serious Games and Learning Version of Existing Games. In: Huseyin, U. The Proceedings of 6th World Conference on Educational Sciences, vol. 191, pp. 487–494. Elsevier (2015) doi: 10.1016/j.sbspro.2015.04.380

[6] Gee, J.P.: What Video Games Have to Teach Us About Learning and Literacy. Computer Entertainment **1**(1), 20–20 (2003)

[7] Malone, T.W.: What Makes Things Fun to Learn? Heuristics for Designing Instructional Computer Games. In: Proceedings of the 3rd ACM SIGSMALL Symposium and the First SIGPC Symposium on Small Systems, pp. 162–169. ACM, New York,NY, USA (1980) doi: 10.1145/800088.802839
[8] Oblinger, D.G.: The Next Generation of Educational Engagement. Journal of Interactive Media in Education **8**, 1–18 (2004) doi: 10.5334/2004-8-oblinger
[9] Herz, J.C.: Gaming the system: what higher education can learn from multiplayer online worlds. EDUCAUSE Publications from the Internet and the University Forum, 169–191 (2002)
[10] Klawe, M.M.: Computer Games, Education and Interfaces: The E-GEMS Project. In: Proceedings of the Graphics Interface 1999 Conference, pp. 36–39. Graphics Interface, Kingston, Ontario, Canada (1999) doi: 10.20380/GI1999.05
[11] Papastergiou, M.: Digital Game-Based Learning in high school Computer Science education: Impact on educational effectiveness and student motivation. Computers and Education **52**(1), 1–12 (2009) doi: 10.1016/j.compedu.2008.06.004
[12] Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., Grau, V., Lagos, F., Lpez, X., Lpez, V., Rodriguez, P., Salinas, M.: Beyond Nintendo: design and assessment of educational video games for first and second grade students. Computers and Education **40**(1), 71–94 (2003) doi: 10.1016/S0360-1315(02)00099-4
[13] Virvou, M., Katsionis, G., Manos, K.: Combining software games with education: Evaluation of its educational effectiveness. Educational Technology and Society **8**(2), 54–65 (2005)
[14] Majek, P., Iida, H.: Uncertainty of game outcome. In: 3rd Int. Conference on Global Research and Education in Intelligent Systems, pp. 171–180. Inter Academia, Hungary (2004)
[15] Why games work and the science of learning, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20130008648.pdf. Last accessed 12 Dec 2018
[16] Schaffer, O.: Crafting fun user experiences: A method to facilitate flow. Human Factors International Whitepaper, 1–18 (2013)
[17] Boggs, L.P.: The Psychology of the Learning Process. The Journal of Philosophy, Psychology and Scientific Methods **4**(18), 477–481 (1907)
[18] Suwanviwatana, K., Terrillion, J.C., Iida, H.: Possible interpretation of mass-inmind: A case study using scrabble. In: eKNOW 2018: The Tenth International Conference on Information, Process, and Knowledge Management, pp. 26–31. IARIA, Rome, Italy (2018)
[19] Agarwal, S., Ram, R., Iida, H.: Measuring force of game information in the brain: Linking game refinement theory and neuroscience. In: 8th International Conference on Knowledge and Smart Technology (KST), pp. 291–294. IEEEXplore Digital Library, Thailand (2016) doi: 10.1109/KST.2016.7440518
[20] Bauer, W., Westfall, G.: University Physics with Modern Physics. 2nd edn. McGraw-Hill (2014)
[21] Kendall, G., Parkes, A., Spoerer, K.: A Survey of NP-Complete Puzzles. ICGA **31**(1), 13–34 (2008)
[22] Cazenave, T.: Nested Monte-Carlo Search. In: Proceedings of the 21st International Joint Conference on Artificial Intelligence, pp. 456–461. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA (2009)

[23] Schadd, Maarten P. D., Winands, Mark H. M., van den Herik, H. Jaap, Chaslot, Guillaume M. J. -B., Uiterwijk, Jos W. H. M.: Single-Player Monte-Carlo Tree Search. In: van den Herik, H. Jaap, Xu, Xinhe, Ma, Zongmin, Winands, Mark H. M. (eds.) 6th International Conference on Computers and Games 2008, LNCS, vol. 5131, pp. 1–12. Springer, Heidelberg (2008)
[24] Coming Soon - New Ranks, https://community.memrise.com/t/coming-soon-newranks/14078. Last accessed 12 Dec 2018
[25] Csikszentmihalyi, M.: Flow: The Psychology of Optimal Experience. Harper and Row (1990)