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Intrinsic vs. Extrinsic Motivation in an Interactive Engineering Game

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Abstract: *In this paper, we study intrinsic vs. extrinsic motivation in players playing an electrical engineering gaming environment. We used UNTANGLED, a highly interactive game to conduct this study. This game is developed to solve complex mapping problem in electrical engineering using human intuitions. Our goal is to find whether there are differences in the ways anonymous players solved electrical engineering puzzles in an electronic gaming environment when motivated to play competitively, as compared to self-regulated play. For our experiments, we used puzzles from four games from UNTANGLED. A one-way analysis of variance (ANOVA) was calculated on participants' scores, type of plays, number of plays, and time spent playing, as both self-regulated and competitive players. We also examined difference between the type of moves used by the competitive and self-regulated players. Our results support the theory of motivation as being internally embedded in learners. The results also demonstrate that a self-regulated learner does not require motivation to improve one's performance.*

Keywords: *Intrinsic Motivation, Extrinsic Motivation, Electrical Engineering Game, Self-Regulated Play, Competitive Play.*

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I. INTRODUCTION

MOTIVATION, a key component in learning, has been studied for decades. A meta-analysis of 20 years of studies on motivation in mathematics education led to the identification of five factors that influence motivation [1]: (1) motivation, or a lack thereof is learned, (2) motivation depends on learners' perceptions of themselves as potentially successful, (3) intrinsic exceeds extrinsic motivation, (4) expectations for learning, and (5) inquiry-based learning environments foster motivation to learn. These factors when considered in general or gaming instructional environments potentially lead to meaningful learning. Self-regulated gaming environments, where players are free to experiment, test skills, and are motivated by reaching an end by their own design, weigh these factors in the design.

The Library Technology Report [2] includes documentation on the need to consider intrinsic motivation as a factor in designing educational games. Studies of game use and learning in educational settings indicate that consideration of intrinsic motivational factors demonstrate the veracity of these factors [3]-[5]. Authors found that when players were intrinsically, self-directed to play games, persistence, success, and goal accomplishment were heightened. Reference [6] used non-invasive tracking mechanisms to determine the level of motivation, adjusting the games internally to accommodate continued levels of self-efficacy and accomplishment by players. Overall, researchers found that in some gaming environments, competition was embedded in the design, with mixed [7]-[9]. Authors found that although competition motivated students to play games, few if any demonstrated a positive effect on learning content. Reference [7] found that competition increased in-game learning, however, the post-test scores did not vary by conditions of competition and collaboration. Reference [8] found that competition was not significantly related to student learning and only partly related to motivation. Reference [9] noted that in a synthetic teaching environment, whereby students taught cyber students algebra concepts, participants were extrinsically motivated to compete with cyber-partners, as long as the partners were weaker than tutors. Performance increased, however, learning goals of mathematics conceptual learning were not met.

In addition to the factors of motivation considered, of concern to some electronic game designers, is the factors of competition. In reference to this [10] an author explained five factors relating to a competitive environment. The author performed a factor analysis to determine the effect of these factors on motivation in an electronic game environment. Reasons or factors for creating a competitive state are: (1) better execution of given task, (2) desire to be successful, (3) motivates and improves future attainments, (4) pleasure in doing good work, and (5) doing complex task. Further the study continued and merged these five into two factors: task and ego orientation. In this paper, the author states that competition cannot be a motivation factor for everyone. A book on competition [11], mentioned that competition is not a good element for accomplishment. Results obtained by reference [12] shows that more than fifty percent of students got motivated after participating in competition. This study concludes that the effect of introducing competition element with less time, incentives and objective helps to motivate and improve students' skills in an e-learning framework. Reference [13] described how quizzes are considered as a competition in game to motivate students. Quizzes in an e-learning environment motivate students to spend more time on completion of a task and resulting in students' increased performance. Quiz modules are included in e-learning to develop the intrinsic motivation which helps to answer the future advanced questions with active experience. This active experience is considered a part of the learning process. Reference [14] noted that the effect of competition on learning outcomes is different among individuals. Comparison is made between students of three different countries and explained how they are motivated in these places. Findings suggested that rewards increase motivation of already motivated students when compared to non-motivated students.

The purpose of this study was to examine the difference between performances of same players in two environments in the UNTANGLED puzzle game: competitive and non-competitive. Data from players who engaged in both environments were examined to determine whether competition served as a motivating factor in successful completion of the puzzle. UNTANGLED was developed to solve mapping problems in electrical engineering using human intuitions.

This paper is organized as follows: Section II explains the significance of scientific puzzle games which are developed to solve engineering problems by harnessing human intelligence. Section III provides the detail explanation on a puzzle game UNTANGLED which is used to underpin our study. Section IV illustrates the performance of participants in regular and competition environments. This paper ends with conclusion and recommendations for STEM in Section V and Section VI.

1. Purpose

This study sought to determine whether there were differences in the ways anonymous players solved electrical engineering puzzles in an electronic gaming framework when motivated to play competitively, as compared to self-regulated play.

II. BACKGROUND

Scientific puzzle games have become very popular lately as scientists are harnessing knowledge and intuition of netizens for solving many research problems. Previous work on puzzle games in references [15]-[23] discussed the importance of puzzle games in finding solution for unsolved problems and focused on analyzing how crowds solve these problems. Studies of [24], [25] shows the impact of using gaming framework to develop the speech and handwriting recognition algorithms. An open mind framework is designed in collaboration with non-experts, software and algorithm developers. In this framework netizens contribution plays a vital role to develop the algorithms [26]. Reference [16] discuss a game which is developed similar to open mind framework to address the challenges faced by visually impaired persons to use image search engine. This multi-player game is designed to label the images on the web, which helps for precise image search. References [27] and [28] illustrates players' performance in providing solutions in a scientific game called Foldit, which is designed by considering challenges like visualization, interaction, scoring and levels to teach. Foldit players provided the solutions for unsolved problems. These games help to solve technical problems by using skills of non-experts and by looking at different aspects of problem. Player's involvement is considered as the crucial factor to serve the purpose of the game.

To engage players for a long period of time, game developers need to meet designing challenges which can motivate players. The scientific games are not only helpful in solving scientific problems but also to teach complex concepts and develop problem solving skills. Reference [29] mentioned that game-based learning can overcome the factors responsible for undermining motivation. The theories developed based on cognitivism, behaviorism, and constructivism helps to understand the significance of games as a pedagogical tool for effective learning and developing problem solving skills. Studies of [30]-[32] illustrates, how games can simplify the concepts of quantum mechanics, simplify programming and designing skills. In reference [3], author emphasizes on synergic and strategic learning to create enthusiasm and enhance skills of participants.

Based on design, features and complexity of a game, every game has different motivational factors which helps to engage the players for playing next levels in the game. Motivation is an important criterion need to be met by the game designers, to achieve goal of a purpose driven games. Studies of [33] suggests that designers need to consider competition as the essential component in games. Integrating competition in educational games can motivate and improve performance of learners. Reference [34] mentioned that how game-based learning with competitive approach affects performance in computer science to develop programming skills. The author called this approach as Competition-Based Learning (CnBL). Reference [35] reviews the advantages between collaborative and competitive environments for learning. The studies on math education conclude that collaborative is more effective and competition between the groups have more benefits than in between individuals. Authors in [36] discussed a framework which is developed to enhance the active learning of students in engineering education. This framework is mainly addressed motivation as an important factor which affects the academic performance of a student. The research conducted in [37] explains how gamification helps to engage students in learning technical concepts and improve their performance in electrical and computer engineering. Similarly, in our study we focus on analyzing the effect of competition to solve electrical engineering problems in a gaming framework.

We conducted this study using an interactive gaming framework UNTANGLED [38] which is developed by our team. It is an online scientific puzzle game to harness human intelligence to solve mapping / placement problems and develop new, efficient mapping algorithms for power-efficient portable devices. The game has received People's Choice Award in the Games & Apps category of the 2012 International Science and Engineering Visualization Challenge conducted by Science and National Science Foundation. The game was released online in 2012 and has been online since then. It has hosted more than 900 players till date. It has a variety of game puzzles and they are arranged according to the level of difficulty. People do not need to have any special engineering background to solve puzzles. They can play this game with light training.

The game has in-depth tutorials that cover information about the gaming interface, rules and guidelines of the game. Participants use random user names or self-selected user names to log in to the game. No demographic information about the players was stored in the database. The only information that is saved is how players solve the game puzzles. The game has a leader board where players can check their standings as compared to other players. The game also has badges, medals as incentives to motivate players. A competition was conducted online from August 10, 2012 to August 20, 2012. To gain participation in the competition, online press releases and university sanctioned posts were used to advertise. Winners of each game and the overall competition were given gift cards. The game has remained online even after the competition. In the results presented in this paper, we considered only those players who played same game puzzles both in regular game setting and competition.

Our approach to conduct this study was to observe players' strategies to solve these puzzles provided in UNTANGLED framework. We also analyzed how players solutions evolve with time. In order to draw meaningful conclusions from extracted data, we performed ANOVA analysis on dependent and independent variables which is discussed in detail in the section IV.

III. EXPERIMENTAL SET-UP

This section explains the experimental set-up used in our study. Players can register to play scientific puzzle game UNTANGLED by using the link, http://untangled.unt.edu/. After registering in this site mentioned, players can choose to play a game of their choice from the list of games available in the framework. Each game is designed based on the different constraints like connectivity, position and components. List of games and other tabs in the environment are shown in Fig. 1. By clicking on the *Leaders* tab, a player can see rank and score obtained by other players who played same puzzle. The rank is based on the score and time taken by the player to solve the puzzle. This gaming environment has the feedback option, where player can give their thoughts or suggestions on the game.

This paper presents results for four games from UNTANGLED which are listed as follows: 4Way, 4Way1Hop, 4Way2Hops, and 8Way. They are as shown in Fig. 2. In 4Way game, each block can connect to four of its immediate neighbors (left, right, up and down). 4Way1Hop is a game in which not only immediate connections are allowed but also horizontal and vertical connections that can skip a block. In 4Way2Hops game, horizontal and vertical connections can skip two nodes. In 8Way, each block can connect to eight of its neighbors (4 horizontally and vertically and 4 diagonally). Institutional Review Board (IRB) protocols were followed to conduct this study. There are seven test graphs taken from the signal and image processing domain for this experimental study. The test graphs are arranged as easy (E1, E2 and E3), medium (M1 and M2) and hard (H1 and H2) levels in the game framework. The information related to the sizes of these test cases is given in Table I.

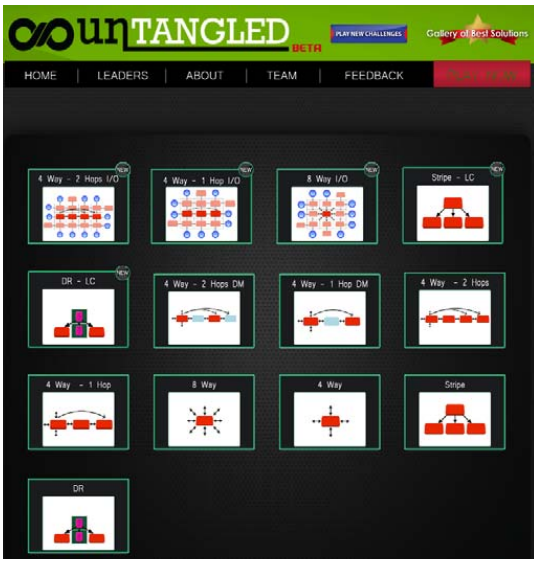

Fig. 1. Window showing games in the framework

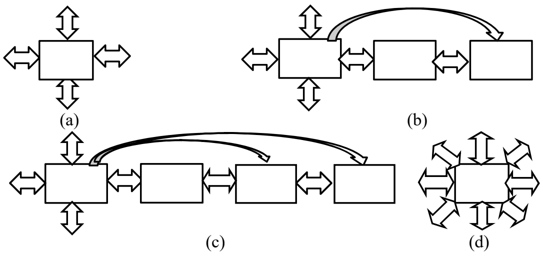

Fig. 2. Connectivity of the four games in UNTANGLED (a) 4Way, (b) 4Way1Hop, (c) 4Way2Hops, and (d) 8Way

TABLE I
BASIC STATISTICS RELATED TO THE TEST GRAPHS

Graphs	E1	E2	E3	M1	M2	H1	H2
Blocks	24	29	29	29	36	52	61
Connections	29	29	34	36	53	63	72

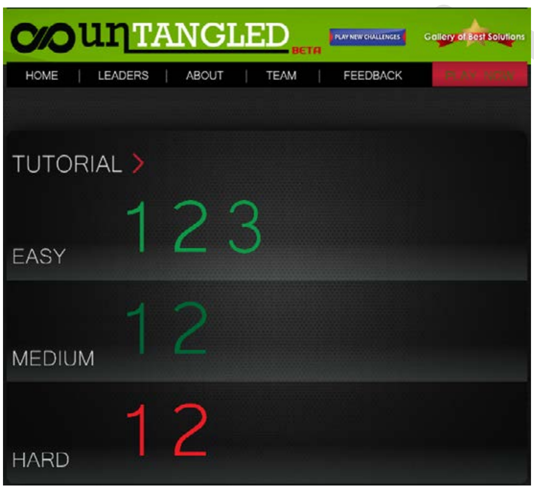

Fig. 3. Window showing seven test graphs. (example is shown for 4Way2Hops game)

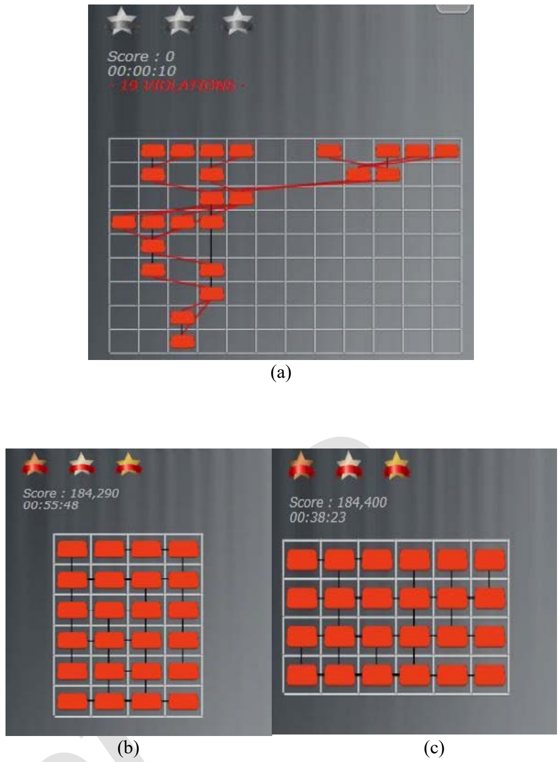

Fig. 4. The unsolved and solved puzzles for 4Way2Hops-E1 game (a) Unsolved Graph (b) Solution – 1 (c) Solution – 2

Figure 3 illustrates the appearance of test graphs according to the level of difficulty (easy to hard) after selecting the game type 4Way2hops. Similar window can be seen to select test graphs for the other three game types 4Way1Hop, 8Way and 4Way. All seven levels are in unlocked state, where player can choose to play any test graph.

As mentioned in the previous section, tutorial helps a player to know how to play a game and introduces the rules and regulations of the game. Tutorials are designed for each game type separately to give brief introduction about the game. Immediately after clicking on any test graph player can start solving a puzzle by reducing number of violations to improve overall score. Fig. 4 illustrates example of unsolved and solved graphs in gaming environment. Fig. 4 (a) shows the 4Way2Hops E1 initial test graph with 19 violations and zero score, and fig. 4 (b), (c) depicts two solutions for the same puzzle, which describes that there are multiple feasible solutions for single puzzle.

IV. DATA ANALYSIS

Participants who completed the puzzles in regular and competitive conditions produced independent scores and types of moves, in both conditions. The number of participants who elected to solve puzzles in both conditions varied by the puzzle being solved as noted in Table II. A range of 1-4 participants elected to solve 4Way puzzles, whereas a range of 5-8 participants elected to solve the 8Way puzzles. Participants varied in the number of puzzles solved under both conditions. Four participants solved puzzles across multiple levels of difficulty with greater frequency across the 24 versions of the puzzles: P1 22/24, P2 16/24, P3 14/24, and P4 9/24. All other participants completed between 1-5 puzzles under both conditions.

TABLE II
NUMBER OF PARTICIPANTS' COMPLETIONS ACROSS TYPES OF PUZZLES

Puzzle types	Participants completing puzzles in both conditions
4Way E1	3
4Way E2	3
4Way E3	3
4Way M1	2
4Way M2	2
4Way H1	1
4Way H2	2
4Way1Hop E1	4
4Way1Hop E2	4
4Way1Hop E3	3
4Way1Hop M1	3
4Way1Hop M2	1
4Way1Hop H1	1
4Way1Hop H2	0
4Way2Hops E1	4
4Way2Hops E2	4
4Way2Hops E3	4
4Way2Hops M1	4
4Way2Hops M2	2
4Way2Hops H1	3
4Way2Hops H2	3
8Way E1	8
8Way E2	6
8Way E3	6
8Way M1	5

TABLE III
ANOVA OF DATA FROM REGULAR AND COMPETITIVE PLAY BY THE SAME PLAYER

		Sum of Squares	df	Mean Square	F	Sig.
number of single moves	Between Groups	128.702	1	128.702	.473	.492
	Within Groups	173425.797	638	271.827		
	Total	173554.498	639			
number of multi moves	Between Groups	15.939	1	15.939	3.015	.083
	Within Groups	3372.522	638	5.286		
	Total	3388.461	639			
number of swap moves	Between Groups	.077	1	.077	.016	.901
	Within Groups	3128.159	638	4.903		
	Total	3128.236	639			
number of add pass moves	Between Groups	86.289	1	86.289	7.283	.007
	Within Groups	7559.197	638	11.848		
	Total	7645.486	639			
number of rem pass moves	Between Groups	3.025	1	3.025	3.849	.050
	Within Groups	501.469	638	.786		
	Total	504.494	639			
total moves	Between Groups	11.556	1	11.556	.028	.867
	Within Groups	262213.638	638	410.993		
	Total	262225.194	639			
total points	Between Groups	276352604.556	1	276352604.556	.009	.924
	Within Groups	19412152310302.890	638	30426571019.284		
	Total	19412428662907.445	639			

TABLE IV
DESCRIPTIVE STATISTICS FOR REGULAR AND COMPETITIVE PLAY

	N	Minimum	Maximum	Mean	Std. Deviation
level	640	1	7	3.03	1.762
single	640	1	200	18.55	16.480
multi	640	0	40	.74	2.303
swap	640	0	14	1.13	2.213
addpass	640	0	48	1.25	3.459
type	640	1	4	2.74	1.093
rem pass	640	0	9	.22	.889
total moves	640	3	218	21.90	20.258
points	640	34660	1028440	197351.38	174296.838

Data were organized for analysis by the categories of: participant, game type (4Way, 4Way1Hop, 4Way2Hops, and 8Way), level of play (regular and competition), specific types of moves (single, multi, swap, rem pass, add pass), total moves, and total points. The levels of easy, medium, and hard were subsumed under the category of game type, with no distinction made for difficulty, primarily due to the small N within each of the 24 separate puzzles.

A series of ANOVAs were conducted on each of the categories, using level of play as the independent variable and the types of moves, total moves, and total points as the dependent variables for comparing self-regulated and competitive choices for approaching the puzzles. Table III shows that the results were not significant at the $p < .05$ level for the following types (single. multi, swap, rem pass, and add pass), as well as total moves, and total points.

The implication is that there is no observed difference in the decisions by players who elected to solve puzzles in either regular or competitive environments. Results of the ANOVA showed significant differences at the $p < .05$ level for the following moves: rem pass and add pass. Although there were significant differences for the two types of plays, rem and add pass, the number of uses of these move choices brings into question the importance of the finding. Overwhelmingly, the results of the analysis indicate that no matter the condition, participants performed the same in both regular and competitive platforms. Table IV provides the descriptive statistics of type of moves used by players in regular and competition environments. From minimum column in the table, we can say that all players who were considered in analysis used single moves. And, larger standard deviation in the last column represents that there is a large deviation in the number of single moves used by players to solve given puzzles in the UNTANGLED game.

Figures 5-9 illustrates the type of moves used in different game sessions with respect to the game type. In figures 5-10, x-axis represents game type and y-axis represents average number of moves used. Regular and Competition game sessions are represented in red and blue colors. Fig. 5 shows that competition and regular participants used almost same number of single moves. This is exceptional in game type 4Way2Hops M2 where there is huge difference between the number of singles moves used by participants of regular and competition game sessions. Fig. 6 shows multi moves used by players in regular and competition game sessions.

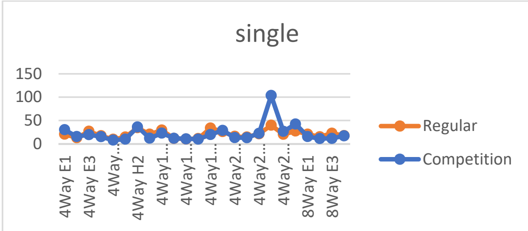

Fig. 5. single moves used in two game session

In a game type 4Way2Hops M2 we can observe a greater number of multi moves are used in the competition game session than in the regular which is similar to single moves in fig. 5. Figure 6 illustrates that irrespective of game session, players used a smaller number of multi moves compared to single moves. Fig. 10 represents total moves used in the competition and regular game sessions. Visualization of total moves used by different game session in different game types is same as the type of moves template used in figures 5-9. In figure 10, x-axis represents the game type and y-axis represents the average number of total moves used by the players to solve different game types. The orange and blue lines in fig. 10 shows regular and competition game sessions which is similar to figures 5-9.

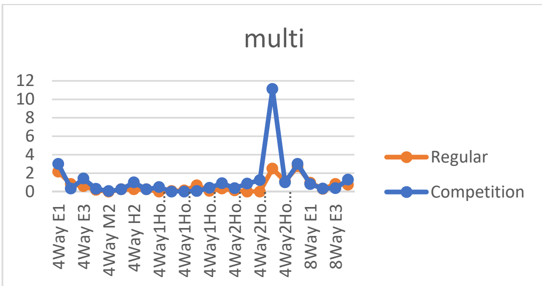

Fig. 6. multiple moves used in two game session

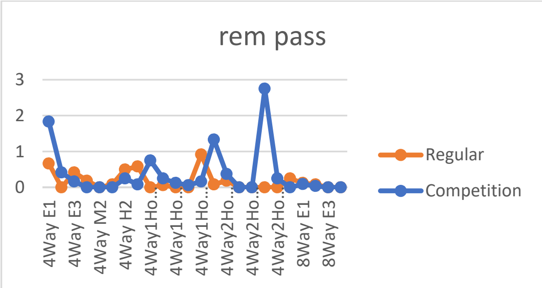

Fig. 7. swap moves used in two game session

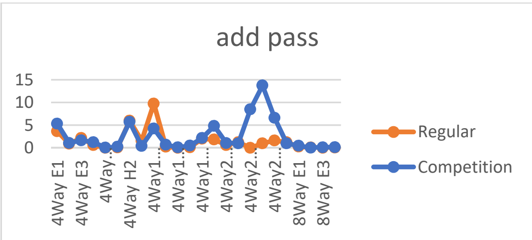

Fig. 8. add pass moves used in two game session

Overall, figures 5-10 shows that almost same number of moves are used in regular and competition game sessions. We can observe slight variation in hard and medium game types, i.e., number of moves used in competition session are more than the number of moves used in regular session. In competition session a greater number of rem pass moves are used in 4Way and 4Way2Hops easy game types. Also, we can observe from these figures 5-10 that there is no difference in the type of moves used by the regular and competition sessions, i.e., regular and competition players used all type of moves to solve the puzzle

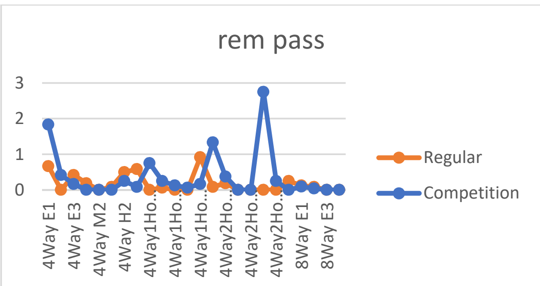

Fig. 9. rem pass moves used in two game session

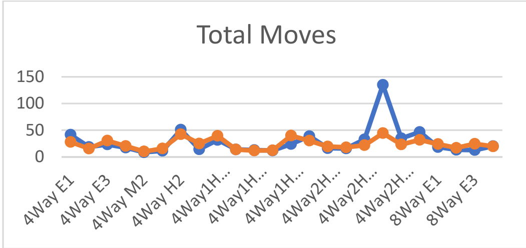

Fig. 10. Total moves used in two game session

Finally, we can conclude that the type of game session (regular or competition) is not showing any effect in the number of moves used or type of moves used by players in different game types. Only in few cases of game type we have observed the difference between the number of moves and type of moves used in two game sessions. For instance, we have observed 4Way2Hops M2 and 4Way2Hops H1 game types show huge difference between number of moves used by regular and competition players.

V. CONCLUSION

The use of competition as a motivational factor in the electrical engineering puzzles did not serve to elevate the score, number of moves, type of moves, and overall scores. These findings support three of the five factors proposed by Middleton and Spanias (2002): (1) motivation depends on learners' perceptions of themselves as potentially successful, (2) intrinsic exceeds extrinsic motivation, and (3) inquiry-based learning environments foster motivation to learn. Participants, who elected to complete puzzles in regular and competitive configurations, demonstrated that a self-regulated learner does not require external motivation to improve. The lack of significant difference between the self-regulated play and the competitive play among the participants supports the theory that motivation is internally embedded in learners, rather than influenced by external factors, such as competition. Data analyzed, represents a small, but complete sample of all players who elected to compete, indicated that players were confident and were able to succeed equally without competition as a motivating factor.

The open, inquiry-based nature of the puzzle solving is served as motivation for participants to succeed, no matter the configuration, regular or competitive.

The puzzles lacked any instructional support, therefore the final two factors: (1) motivation is learned, and (2) expectations for learning, were not apparent in the comparison. However, these findings have implications for educationally supported environments, both electronically and physically. Teachers who use gaming in instruction, and game designers using motivational theory to design games, could potentially increase the level of success among less confident learners by considering these two factors of motivation, directly related to teaching through expectations and setting up learning opportunities that are motivational. The participants' data examined in this study clearly show a group that was confident, motivated by internal factors, and with minimal need for external support. However, these participants represented a small fraction of the participants who chose to engage in the UNTANGLED electrical engineering puzzle games. In order to increase the number of confident players, intervention on the part of a teacher and/or cyber-teacher who increments learners toward success in self-regulated learning, would be required. The inquiry-based learning environment of the UNTANGLED game lent to the potential of success for all players, however, the data support the notion that in order to increase the number of confident completers, additional instructional support would have been necessary.

The findings did not support the competition theories purported by Franken and Brown (1995). Participants in this study showed no difference in execution and completion of complex tasks. Instead, the players who elected to engage in UNTANGLED show no significant differences in plays selected, scores obtained, and number of plays. Players elected the complex tasks, as evidenced by the choice to play at all levels, easy to hard, refuting the notion that competition contributed to choices for complex tasks. The future attainment of improvement was refuted as well, since the players who chose to both regular and competitive showed no significant differences in any categories. The lack of support for theoretical premise suggests that further study is necessary to determine the plausibility of the theory and practice of gaming choices when competition is included.

As electronic environments for learning increase in classrooms, teachers and instructional game designers must find a way to use the factors of motivation to support increased learning. Currently, educators and designers are encroaching on ways to make learning meaningful, however, the current climate of game design as testing skills remains outside the purview of excellence in learning. Likewise, with a drive in the educational field toward testing, rather than learning, teachers are using electronic platforms for drills, rather than meaningful learning. A collaboration between educators and game designers, with the factors of motivation at the center of design and delivery, could lead to higher levels of learning for more students, rather than a handful of confident, intrinsically motivated learners, who would succeed with or without competition.

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

VI. RECOMMENDATIONS

As STEM (Science, Technology, Engineering and Mathematics) continues to lead educational thought, coupled with the use of electronic means by which to teach, learn and test, it is recommended that a paradigm shift occur in the fields of education and technology. Currently, funding and testing, hence teaching, primarily support the science and mathematics, leaving limited emphasis on technology and engineering. Although schools, even as young as elementary grades, provide students with opportunities to engage in robotics competitions and other activities that enhance initial levels of engineering and technology engagement. However, because these are not tested subjects, rarely are students afforded opportunities to explore and examine the tenets of technology and engineering that require experimentation, rather than tested book learning as noted in mathematics and science STEM fields. Through more kinesthetic and spatial learning opportunities, void of competition with the intent to intrinsically motivate learning, the TE in STEM would be strengthened. This would require a paradigm shift in the education field, as well as the technology and engineering fields.

Currently, technological games used in educational environments serve to drill students in tested areas, particularly mathematics and reading. Some evidence points to increase in test scores as a result of this application of technology, with no evidence of students driven toward using technology to increase learning the spatial reasoning needed to become engineers. Technological games outside the field of education are designed primarily for entertainment and competition. Players can enter new worlds, find solutions to complex circumstances, and gain points toward winning levels of recognition or prizes. Melding the two approaches could potentially lead to the development of engineers. The UNTANGLED puzzles were designed to ascertain how self-selected participants elected to solve the puzzles, which were solutions to electrical engineering problems. In a STEM environment where technological games are used to teach students the spatial reasoning needed to complete engineering puzzles, solve technological problems that lead to an understanding of new worlds of learning in many fields, within the realm of intrinsic motivation, rather than competition, could potentially lead to higher levels of engaged learning overall.

Change from a static educational system, driven by testing in mathematics and science, while rewarding only the most talented with the opportunity to attend STEM academies, limits learning and identification of engineers. Educators and gaming engineers would serve the learning population of children of all ages by banding together to find an alternative. The example of the alternative is the UNTANGLED puzzle. In this design, potential engineers are tested, which is a beginning. The adjustment the puzzles to teach the spatial reasoning necessary to solve the puzzles would serve to begin to develop engineers. A further adjustment of teaching for intrinsic motivation would enhance the development of engineering thinkers further. All these adjustments would require a paradigm shift away from rote teaching and testing to engaged, inventive, exploratory learning that could lead to new dimensions of STEM education. Educators, engineers, scientists, technology experts, mathematicians must band together to challenge the system and call for reform. With a need for alternate approaches to the care and development of energy, food sources, environmental care, and more, teaching students to use all STEM knowledge and skills will be paramount. Affecting this change will be the responsibility of everyone in these fields.

REFERENCES

1. Middleton, J.A. and Spanias, P.A., 2002. Findings from research on motivation in mathematics education: What matters in coming to value mathematics. Lessons learned from research, 30(9).

2. Kim, B., 2015. Designing Gamification in the Right Way. Library Technology Reports, 51(2), pp.29-35.

3. Ciampa, K., 2014. Learning in a mobile age: an investigation of student motivation. Journal of Computer Assisted Learning, 30(1), pp.82-96.

4. Phillips, V. and Popović, Z., 2012. More than child's play: Games have potential learning and assessment tools. Phi Delta Kappan, 94(2), pp.26-30.

5. Williams, D.L., 2007. A Unique Review Strategy that Motivates Student Learning. InSight: A Collection of Faculty Scholarship, 2, pp.64-69.

6. Felicia, P., 2009. Modelling players' behaviours and learning strategies in video games. In Proceedings of the 3rd European conference on games-based learning (pp. 120-123). Reading, UK: Academic Publishing.

7. Plass, J.L., O'keefe, P.A., Homer, B.D., Case, J., Hayward, E.O., Stein, M. and Perlin, K., 2013. The impact of individual, competitive, and collaborative mathematics game play on learning, performance, and motivation. Journal of educational psychology, 105(4), p.1050.

8. Vandercruysse, S., Vandewaetere, M., Cornillie, F. and Clarebout, G., 2013. Competition and students' perceptions in a game-based language learning environment. Educational Technology Research and Development, 61(6), pp.927-950.

9. Matsuda, N., Yarzebinski, E., Keiser, V., Raizada, R., Stylianides, G.J. and Koedinger, K.R., 2013. Studying the effect of a competitive game show in a learning by teaching environment. International Journal of Artificial Intelligence in Education, 23(1-4), pp.1-21.

10. Franken, R.E. and Brown, D.J., 1995. Why do people like competition? The motivation for winning, putting forth effort, improving one's performance, performing well, being instrumental, and expressing forceful/aggressive behavior. Personality and individual differences, 19(2), pp.175-184.

11. Gredler, G.R., 1991. KOHN, A, 1986. No contest: The case against competition. Boston: Houghton Mifflin, 257 pp., Psychology in the Schools, 28(2), pp.182-183.

12. Cantador, I. and Conde, J.M., 2010. Effects of competition in education: A case study in an e-learningenvironment.

13. Worm, B.S. and Buch, S.V., 2014. Does competition work as a motivating factor in e-learning? A randomized controlled trial. PloS one, 9(1), p.e85434.

14. Sternberg, H. and Baalsrud-Hauge, J., 2015. Does competition with monetary prize improve student learning? – An exploratory study on extrinsic motivation. In Lunds universitets utvecklingskonferens, 2015. Lund University.

15. Terry, L., Roitch, V., Tufail, S., Singh, K., Taraq, O., Luk, W. and Jamieson, P., 2009, July. Harnessing Human Computation Cycles for the FPGA Placement Problem. In ERSA (Vol. 9, pp. 188-194).

16. Von Ahn, L. and Dabbish, L., 2004, April. Labeling images with a computer game. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 319-326). ACM.

17. Von Ahn, L., Blum, M. and Langford, J., 2004. Telling humans and computers apart automatically. Communications of the ACM, 47(2), pp.56-60.

18. Von Ahn, L., Ginosar, S., Kedia, M., Liu, R. and Blum, M., 2006, April. Improving accessibility of the web with a computer game. In Proceedings of the SIGCHI conference on Human Factors in computing systems (pp. 79-82). ACM.

19. Von Ahn, L., Liu, R. and Blum, M., 2006, April. Peekaboom: a game for locating objects in images. In Proceedings of the SIGCHI conference on Human Factors in computing systems (pp. 55-64). ACM.

20. Von Ahn, L. and Dabbish, L., 2008. Designing games with a purpose. Communications of the ACM, 51(8), pp.58-67.

21. Sunstein, C.R., 2006. Infotopia: How many minds produce knowledge. Oxford University Press.

22. Surowiecki, J., 2005. The wisdom of crowds. Anchor.

23. Michelucci, P. ed., 2013. Handbook of human computation (Vol. 2, No. 3). New York: Springer.

24. Stork, D.G. and Lam, C.P., 2000, July. Open Mind Animals: Ensuring the quality of data openly contributed over the World Wide Web. In AAAI Workshop on Learning with Imbalanced Data Sets (pp. 4-9).

25. Hearst, M.A., Hunson, R.D. and Stork, D.G., 1999. Building intelligent systems one e-citizen at a time. IEEE Intelligent Systems and their Applications, 14(3), pp.16-20.

26. Stork, D.G., 1999, September. Character and document research in the open mind initiative. In Document Analysis and Recognition, 1999. ICDAR'99. Proceedings of the Fifth International Conference on (pp. 1-12). IEEE.

27. Cooper, S., Khatib, F., Treuille, A., Barbero, J., Lee, J., Beenen, M., Leaver-Fay, A., Baker, D. and Popović, Z., 2010. Predicting protein structures with a multiplayer online game. Nature, 466(7307), p.756.

28. Cooper, S., Treuille, A., Barbero, J., Leaver-Fay, A., Tuite, K., Khatib, F., Snyder, A.C., Beenen, M., Salesin, D., Baker, D. and Popović, Z., 2010, June. The challenge of designing scientific discovery games. In Proceedings of the Fifth international Conference on the Foundations of Digital Games (pp. 40-47). ACM.

29. Van Eck, R., 2006. Digital game-based learning: It's not just the digital natives who are restless. EDUCAUSE review, 41(2), p.16.

30. Anupam, A., Gupta, R., Naeemi, A. and JafariNaimi, N., 2018. Particle in a Box: An Experiential Environment for Learning Introductory Quantum Mechanics. IEEE Transactions on Education, 61(1), pp.29-37.

31. Klopfer, E., Scheintaub, H., Huang, W., Wendel, D. and Roque, R., 2009. The simulation cycle: Combining games, simulations, engineering and science using StarLogo

TNG. E-Learning and Digital Media, 6(1), pp.71-96.

32. Chen, N.S., Hung, I.C. and Wei, C.W., 2010, April. Developing Ubiquitous Learning System with Robots for Children. In the Third IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning (pp. 61-68). IEEE.

33. Cagiltay, N.E., Ozcelik, E. and Ozcelik, N.S., 2015. The effect of competition on learning in games. Computers & Education, 87, pp.35-41.

34. Burguillo, J.C., 2010. Using game theory and competition-based learning to stimulate student motivation and performance. Computers & Education, 55(2), pp.566-575.

35. Ke, F. and Grabowski, B., 2007. Gameplaying for maths learning: cooperative or not? British Journal of Educational Technology, 38(2), pp.249-259.

36. López-Fernández, D., Alarcón, P. P., & Tovar, E. (2015, March). Motivation in engineering education a framework supported by evaluation instruments and enhancement resources. In Global Engineering Education Conference (EDUCON), 2015 IEEE (pp. 421-430). IEEE.

37. Marasco, E., Behjat, L., Eggermont, M., Rosehart, W., Moshirpour, M., & Hugo, R. (2016, October). Using gamification for engagement and learning in electrical and computer engineering classrooms. In Frontiers in Education Conference (FIE), 2016 IEEE (pp. 1-4). IEEE.

38. Mehta, G., Crawford, C., Luo, X., Parde, N., Patel, K., Rodgers, B., Sistla, A.K., Yadav, A. and Reisner, M., 2013. Untangled: A game environment for discovery of creative mapping strategies. ACM Transactions on Reconfigurable Technology and Systems (TRETS), 6(3), p.13.