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The Mind Fitness Program© Provides Training for STEM Careers

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Abstract

The **Mind Fitness Program©,** has been created to prepare the participants for Science, Technology, Engineering, and Math (STEM) careers by stimulating their spatial skills, 3D visualization, analytical abilities, abstract thinking, pattern recognition skills, memory, attention to detail, and general mental performance.

The program was initially developed for the Engineering Program at San Antonio College in San Antonio and two of the components were previously presented in two ASEE papers. The program has been expanded and was successfully tested in 2022 during the final year of the Lunar Caves Analog Test Sites (LCATS) Program offered by the WEX Foundation. It is presently in use at the DoSeum, a children's museum located in San Antonio, Texas. It has been presented at Alamo STEM Ecosystem Educator Conference and several schools in the San Antonio area.

It uses a variety of exercises designed to challenge different areas of the brain; just as physical exercises affect various muscle groups. The exercises are disguised as games since one of the most recent trends in education is the "edutainment" concept. It combines educational content with entertaining activities so, the participants learn while having fun.

The program is extremely flexible and can be adapted to various locations, number of participants, or time intervals, and applies to all age brackets with educational applications. It is designed to be offered in multiple stages of complexity, and the length of each stage may be modified as needed.

This paper will present the program, the results of initial testing, and the plans for future expansion of the program to reach a broader range of participants.

Introduction

According to the National Assessment of Educational Progress [1], the average reading and math scores were lower for 9 and 13-year-olds in 2020 than in 2012, marking the first time both scores for this age group declined between assessments. Additionally, 4th and 8th graders in the U.S. ranks below the 30th percentile out of 64 and 46 participating educational systems worldwide, respectively. Similarly, many students lack spatial visualization skills or the ability to think in three dimensions, which is critical in STEM careers.

The visual thinking and ability to visualize in a 3D environment has been defined as the ability to mentally imagine, understand, rotate, and manipulate geometric objects in a 3D environment [2-4], and it is an essential skill for success in STEM careers. Spatial skills are very important for a large variety of careers, particularly STEM careers. In 1964 Smith, I.M. [5] identified at least 84 career areas for which spatial skills are important. Studies have shown that spatial visualization skills are a strong predictor of the success and confidence of engineering students [6-10].

Unfortunately, this concept is often missing from K-16 curricula and as a result, the skill is underdeveloped in many students. This deficiency is universal and is generated in large part by the introduction of computer games and television in early developmental stages. Looking at a flat screen exposes children to a two-dimensional environment and reduces their playing time with physical 3D objects, missing the opportunity to develop hand-eye coordination that is the foundation of spatial skills.

Continuous efforts have been made to create training methods and exercises that increase spatial visualization skills. In 2003 Sorby, S., A., Wysocki, A. F., and Baartmans B. J., published a

multimedia software-workbook package which contained the course "*Introduction to 3D Spatial Visualization"* [11], now used for engineering graphics education throughout the nation. In 2009 Sorby, S.A. identified several strategies that can be effective in developing 3-D spatial skills and in contributing to student success [12]. In 2013 Uttal, et al. [13], published a meta-analysis of more than 200 studies on improvement of spatial skills and found that the average effect size of improvement for students who receive extensive training and practice on spatially-relevant skills, such as mentally rotating 3D shapes, was .53 (equivalent to an intervention improving SAT scores by more than 50 points or IQ scores by more than 7.5 points). They also found that the improvements provided by training last over time, long after the training was completed.

Current research [14] adds more evidence that spatial ability impacts mathematical learning in children indicating that improving visuospatial working memory and non-verbal reasoning are the most effective avenues for enhancing math performance. Improving math performance improves students' confidence in studying other STEM related disciplines.

In 2019, NSF, the Organization for Economic Cooperation and Development (OECD), the US National Academies of Sciences, Engineering, and Medicine (NASEM), and the University of Southern California sponsored a workshop, with global participation, to explore actions that would facilitate convergence in education [15]. This workshop addressed the outlook and needs for applying convergence across the stages of preK-20 education. Convergence education implies a multidisciplinary approach of STEM subjects. A literature review was done to establish a basis of reference for further understanding convergence education and its relationship to transdisciplinary learning or integrated STEM education [16, 17].

All of these studies combined with the need to improve students' performance in STEM related fields provided a window of opportunity to develop a training program dedicated specifically to enhancing their mental abilities needed in a variety of STEM disciplines. Our Mind Fitness Program© is a perfect example of the new convergence education concept as it transcends a singular discipline curriculum to address fundamental aspects of STEM education. It has been created to prepare the participants for STEM careers in general by stimulating their spatial skills, 3D visualization, abstract thinking, analytical abilities, pattern recognition skills, memory, attention to detail, and their general mental performance.

The Early Stages

The program's development started in 2004. In the early stages, simple exercises were incorporated in the engineering program at San Antonio College. The exercises were created to develop the spatial skills students needed to succeed in their selected engineering career. Several of these exercises were collected in a book "A, B, See…In 3D" [18] published in 2015. This new method, with the analysis of the initial results, was described in a paper "A New Way to Help Students Improve 3D Visualization" [19] presented at the 2016 ASEE conference in New Orleans.

To reach a younger audience this new method was developed as a game, KryptoGlyphs™. The game received "The Best Educational Concept" award at the 2017 Chicago Toys and Games Convention.

Over the years, more training methods and exercises, many of them disguised as games, have been created. Several of them have been informally presented in a variety of settings at several schools from our area. They were all received positively by educators and students alike.

One of the methods generated a new book, "Counting Bricks from Ancient Ruins" [20] published in 2017. Again, the new method with the analysis of the initial results was described in a paper, "A Simple Method to Help Students Improve 3-D Visualization" [21] presented at the 2020 ASEE conference in Montreal.

Program Expansion

The popularity of the program continued to expand reaching new partners and providing new opportunities to validate its capabilities. Its increased complexity created the need to expand the operating format into a more formal entity. In August of 2020, a new company "3D LoneStar LLC" [22] was formed to produce and distribute educational materials and programs.

The program, by design, requires a coach and is extremely flexible and adaptable to various conditions, locations, and available time schedules. The program starts with a brief presentation of the design concept and the tools and skills needed to do it successfully. This is done to help students understand the need for this kind of training. Then the program continues with the practical components. The program has ten components divided in two categories: Core Components (Appendix 1) and Auxiliary Components (Appendix 2).

Core Components:

- PICK PUT PEGS
- PUZZLEBUILD
- KRYPTOGLYPHS™
- TOUCH'N TELL
- COUNTING BRICKS

Auxiliary Components:

- A-MAZE-ING
- DOT 2 DOT
- FONT CHALLENGE
- WORD HUNT
- SCRAMBLED DROWS

The Core Components create the foundation of spatial visualization, pattern recognition, abstract thinking, and attention to details. The Auxiliary Components further increase the pattern recognition, abstract thinking skills, and attention to details.

All Core Components require diverse materials that provide specific challenges with various levels of difficulty for brain stimulation while the Auxiliary Components are played mainly on paper and require just a pencil and an eraser. A computer with a projector and a screen is optional but it is helpful when used to analyze the games and provide feedback if necessary.

All Component challenges may be adjusted, alternated, extended, or repeated as decided by the coach. The ideal duration for the program would be six weeks with daily meetings of 45 minutes but it can be extended to a full semester or reduced partially to one week or two depending on the available time. One important element to be considered is that the effectiveness of the program depends directly on the frequency and the time spent on task by the participants.

The DoSeum Partnership

One of the first expansions of the program was through a partnership with the DoSeum [23]. The DoSeum is a children's museum located in San Antonio, TX that served over 320,000 guests in 2022. On May 5th, 2022 a Memorandum of Understanding was signed between the DoSeum and 3D LoneStar Company to implement the Mind Fitness Program©. At the end of 2022, instructors

at The DoSeum introduced camp students (from ages 8-11) to a simplified version of the Mind Fitness Program©, including Pick Put Pegs, KryptoGlyphs™, and Touch N'Tell. In this introduction, instructors assessed student engagement with the Core Components to promising results. Students were invited to explore the listed Core Components when they arrived to The DoSeum during camp drop-off. On the third day we gave students the option to watch a children's cartoon, which is the traditional activity during drop-off, or continue playing with the Mind Fitness Core Components. The students opted to play with the Core Components while cartoons played in the background. Additionally, instructors noted that students played with the Core Components in increasingly complex ways. Particularly, students self-regulated their graduation from the 3 x 3 holes, to 4 x 4 holes, to 5 x 5 holes versions of Pick Put Pegs.

LCATS Partnership

The Lunar Caves Analog Test Sites (LCATS) program [24] supported by a NASA grant is designed to acquaint students with professional opportunities in Space-STEM through training, sustained research, field experiences, and mentorship. Between December 4, 2021 and May 21, 2022, the last component of the program was provided by the WEX Foundation at the UTSA campus. There were 12 in-person sessions scheduled on alternate Saturdays from 9:00 am – 12:00 pm. Through a mutual agreement, at the end of each session, one hour has been reserved for a reduced version of the Mind Fitness Program© that included four Core Components, the Pick Put Pegs, the PuzzleBuild, the KryptoGlyphs™, and Counting Bricks. At the beginning and end of the program a pre and post-test was administered to evaluate the aptitudes gain as a result of the program. The test was a compilation of Purdue Spatial Visualization Test (PSVT) [25], Vandenberg Mental Rotation Test (MRT) [26], Spatial Reasoning Test (SRT) [27], and Mental Cutting Test (MCT) [28].

Initially there were 18 middle school students enrolled in the program but only ten effectively finished it. Since the attendance was voluntary occasionally some students missed one or two sessions due to family obligations. The first and last sessions were reserved for evaluation testing and one session was cancelled due to a COVID19 protocol, leaving only nine sessions of 50 minutes for effective training, spread over at least two weeks intervals in between. The training content had to be adapted to a modified two week schedule and spread over available number of sessions so we could maximize the students' exposure to our most essential Core Components.

Despite all these inevitable limitations the results demonstrate the program potential.

	Start	End	Gain	No Gain	Loss
# of Students	18	10	8	1	1
Female	4	3	3	0	0
Male	14	7	5	1	1

Table 1 – Participation and Test Results for the LCATS cohort

Table 1 shows the number of students participating in the pre and post evaluation tests and how many showed an increase in correct answers after finishing the program. The average increase in correct answers was 15.71% between the pre and post-tests. Eight students showed an increase in correct answers, one had none, and one had lower correct answers. All female participants demonstrated an increase in correct answers. Without being overwhelmingly compelling, the

results provide an incentive to continue studying the effects of increasing the focus and the exposure time combined with reducing the time interval between sessions.

At the end of the program, an on-line Program Evaluation Questionnaire (Appendix 3) was administered and the main results are presented in Table 2.

The program was fun	The program was engaging	I learned a lot in this program	Overall, I would give this program a positive rating	The games were challenging
5 +	5 +	4 +	6 +	5 +
5 Neutral	4 Neutral	4 Neutral	3 Neutral	3 Neutral
0 -	1 -	2 -	1 -	2 -

Table 2 – Program Evaluation by LCATS Participants

Other Outreach Activities

Throughout 2022 the program was presented to several schools from different independent school districts in the San Antonio area, including charter schools.

Future Developments

The increased interest in STEM education offers us the opportunity to increase our partnerships and improve and expand our Mind Fitness Program© to respond to a larger variety of challenges presented by our complex society.

Following the successful introduction to the Mind Fitness Program©, The DoSeum plans to assess engagement with children between the ages of 5-7. Additionally, The DoSeum will offer a 5-day summer camp fully dedicated to the Mind Fitness Program©. In this upcoming summer camp, DoSeum will assess students' reading and visual thinking skills before and after the camp, and challenge students to develop their own games using the Core Components.

The Mind Fitness Program© is a work in progress. Several summer camps are in the planning stages at various schools and learning centers in our area. The program may be tailored and modified to fit their students' needs. New components will be added to increase the diversity of challenges and respond to the continuously increasing demand for more detailed and specific learning objectives.

These learning aids and games are developed with an educational concept to sharpen children's knowledge and encourage their natural curiosity, promoting open-ended learning. They are multi-purpose learning tools encouraging the development of skills in an engaging way through play. Additionally, through the formation of 3D Lonestar LLC, we are working with agencies and retailers to make these tools more readily available.

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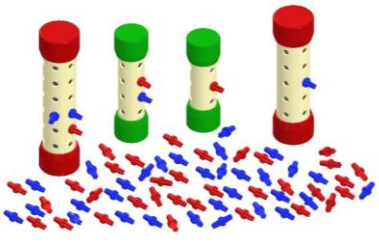
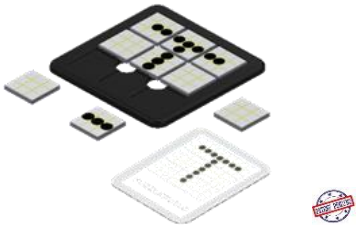
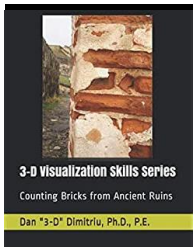
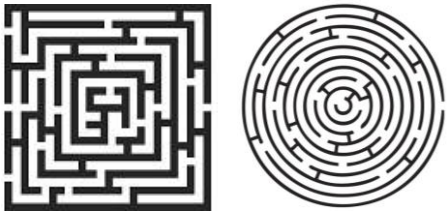
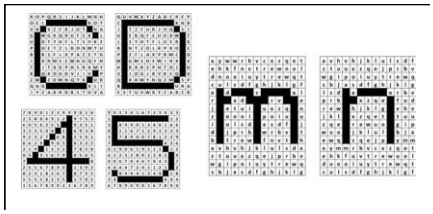
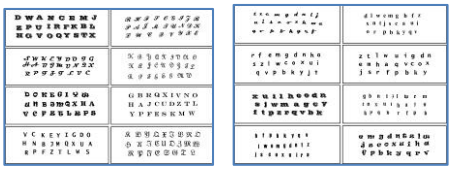
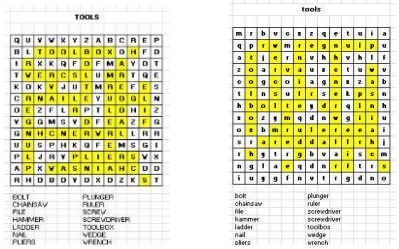
APPENDIX 1

Core Components

	***PICK PUT PEGS*** games is a challenging set of two player games in which players alternately place one peg in a hole. The winner is the first player that puts the pegs in a full formation – column, ring, or a diagonal. The challenge of the games is the fact that almost half of the playing area is obscured by the cylindrical body so the players must develop a mental image of the whole playing area.
	***PUZZLEBUILD™*** is a game that increases the players' level of abstract thinking, pattern recognition, visualization skills, and attention to detail by creating puzzle shapes from modular components. The basic game uses nine tiles with dot designs to form letters and numbers.
	***TOUCH'N TELL*** is a tactile recognition game in which the players attempt to name the letters they touch on tiles without seeing them. The game has two discs, one showing only capital letters and one only lower case letters. Each disc has on one side the outward extruded figures while the cavity figures and are on the opposite side.
	***KRYPTOGLYPHS™*** is a challenging and unique single and multi-player game that increases the players' level of abstract thinking and 3-D visualization skills. Each 3D letter module shows at least three different letters out of which at least one is a vowel. The game may be expanded to include numbers and plane geometric shapes.
 	***COUNTING BRICKS*** is a challenging and unique new set of educational activities based on popular LEGO bricks that increases the players' level of abstract thinking and visualization skills by creating 3D formations from modular components. The game is based on a new concept of visualization exercises presented for the first time in a book format under the title "Counting Bricks from Ancient Ruins".

APPENDIX 2

Auxiliary Components

	***A-MAZE-ING*** is a game played on panels containing various shapes of labyrinths. The mazes are to be played in order from the simple ones to more complex. All players use the same panel and start solving the maze at the same time. The setting may be collaborative or competitive. At a more advanced stage the players are invited to create their own labyrinths and exchange them with other players.
	***DOT 2 DOT*** *is* a game that uses printed grid panels. The grids are filled with letters and numbers. Each grid has one letter or number arranged in a pattern that when all the squares containing it are colored it will reveal a digitized image of the respective letter or number. The game has four sets of challenges. An advanced level uses the same concept but the revealed figure is always a different one from the colored one.
	***FONT CHALLENGE*** game *is* a challenging new and unique type of educational game that increases the players' level of abstract thinking, visualization, and pattern recognition skills using printed panels. The game uses panels filled with capital and lower case letters printed with eight different fonts at two scales, a large one and a small one. The players must identify random letters.
	***WORD HUNT*** is a game played on grid panel filled with letters. The letters displayed on the grid are either capital letters or lower case letters. The players are challenged to find the words in the grid. The words can be read horizontally, vertically, or diagonally in either one of the eight directions. The game can be played competitively, timed, or just to reach a personal best.
5 LETTERS REGIM = GRIME; huslp = plush **6 LETTERS** CETOPK = POCKET ; penpah = happen	***SCRAMBLED DROWS*** is a game played on paper displaying apparently random letters that, when properly arranged show a regular word. Some of the letter groups are capital letters and some groups contain lower case letters. The players are provided with one or several scrambled words and invites the players to unscramble them. It can be played competitively, timed, or just to reach a personal best.

APPENDIX 3

Age: ____

Gender: M F

Mind Fitness Program Evaluation

Please circle the choice that represents your closest opinion:

Evaluation of the program:	**Disagree**	**Neutral**	**Agree**
The program was fun	X	X	X
The program was engaging (I wanted to try all activities)	X	X	X
I learned a lot in this program	X	X	X
Overall, I would give this program a positive rating	X	X	X
Evaluation of the trainer:			
The trainer explained well what I needed to do	X	X	X
The materials were organized in a good sequence	X	X	X
The trainer was helpful in class	X	X	X
Evaluation of the content:			
The lectures were informative	X	X	X
The games were challenging	X	X	X
The test was too easy	X	X	X

Rating of individual games:

Please rate each game you played from **1** (boring) to **5** (exciting)

Pick Put Pegs	**1**	**2**	**3**	**4**	**5**	**N/A**
3x3	X	X	X	X	X	X
4x4	X	X	X	X	X	X
5x5	X	X	X	X	X	X
6x6	X	X	X	X	X	X
PuzzleBuild	X	X	X	X	X	X
KryptoGlyphs	X	X	X	X	X	X
Counting Bricks	X	X	X	X	X	X

What would you like to change in the program?