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Inclusive Physical Education of Students with Disabilities Due to War Injuries: Restoration of the Functions of the Lower Extremities

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Background. The relevance of the study is because the institutions of higher education are now tasked with creating all the conditions for the recovery of body functions lost as a result of injuries of students with disabilities, which additionally actualizes the stated problem in connection with the long-term hostilities on the territory of Ukraine.

Objectives. The purpose of the article is to reveal the effectiveness of the developed program of inclusive PE on the recovery of lost functions due to injuries of the lower limbs in students with disabilities.

Materials and methods. To solve the tasks, a complex of scientific intelligence methods was used at the empirical and theoretical level: literature analysis, observation, testing, experiment, and methods of mathematical statistics. The test program consisted of the star excursion balance, weight-bearing lunge test, and the single leg stance test. 24 male students with disabilities in the first year of study at a higher education institution took part in the experiment.

Results. According to the qualitative assessment of the obtained results, it can be stated that after the end of the experiment, there is a general tendency to increase the results of the test tasks. A significant improvement of the indicators was found in all the investigated parameters without exception: as a positive trend in the range of 15% is observed. The results of the static and dynamic tests performed with support on the injured leg were significantly lower than with support on the uninjured leg ($p < 0.05$).

Conclusions. The results of the final testing allow us to ascertain the effectiveness of the implemented program. Statistically reliable positive dynamics of the set of investigated indicators proved that the implementation of the developed inclusive PE program for students with disabilities due to injuries of the lower extremities ensures the effectiveness of recovery due to functional injuries.

Keywords: inclusion, physical education, student with disabilities, war trauma, program, effectiveness.

Introduction

Since the armed aggression of Russia on the territory of Ukraine in 2014, society and the state have faced a challenge, when a large number of people from among the participants in hostilities and the civilian population acquired the status of disability due to injuries. After the start of the full-scale invasion, the number of injuries, including multiple blast injuries, increased significantly (Shvets, Horishna, Deputat, Rychka, Zhaldak, & Kih, 2022).

As a result, in the conditions of a long war, the number of students with disabilities due to injuries in institutions of higher education is permanently increasing. Institutions of

higher education are tasked with creating all the conditions for restoring functions lost as a result of injuries and improving the health of students with disabilities (Page, Anderson, & Charteris, 2021), which additionally actualizes the stated problem in connection with the long-term hostilities in the territory of Ukraine.

The relevance of the identified issues is determined by the fact that everyone can face in Ukraine today – injuries as a result of military operations. Statistics show that 70% of war injuries are extremity injuries (Shvets, Horishna, Deputat, Rychka, Zhaldak, & Kih, 2022). Of all persons requiring rehabilitation, the most common types of injuries during military conflicts are injuries of the lower extremities (64.3%) (McKinley, D'Alleyrand, Valerio, Schoebel, Tetsworth, & Elster, 2018), especially among military personnel, sprained an-

kles are very by widespread trauma (Waterman BR, Belmont, Cameron, Deberardino, Owens, 2010). It is also important that 50–70% of cases of diseases of various etiologies develop after an injury if timely rehabilitation measures are taken to restore the lost functions of the limbs (Doherty, Delahunt, Caulfield, Hertel, Ryan, & Bleakley, 2014; Al-Mohrej, & Al-Kenani, 2016).

The identified question becomes especially relevant given the fact that the timely restoration of affected functions in students with disabilities is a factor in preventing physical maladaptation of such students and ensuring their further ability to effectively perform their professional activities (Goodwin, & Watkinson, 2020; Blavt, 2022). Landmarks for solving this problem are considered from the standpoint of inclusive education (Grenier, Patey, & Grenier-Burtis, 2022) using forms, means, and methods of physical education (PE) (Kuntjoro, Soegiyanto, Setijono, & Suharto, 2022; Pocock, & Miyahara, 2018).

Despite the obvious interest of scientists in the issues of restoration of the affected functions as a result of war injuries of students with disabilities in the modern scientific discourse, we note the low degree of its systematic comprehensive study about higher education.

The purpose of the article is to reveal the effectiveness of the developed program of inclusive PE on the restoration of lost functions due to lower limb injuries in students with disabilities.

Material and Methods

Study Participants

24 male with disabilities in the 1st year of study from Lviv Polytechnic National University and Drohobych Ivan Franko State Pedagogical University were involved in the experimental study (Tab. 1).

The results of the screening of health risks related to participation in the experiment and the absence of pronounced symptoms of trauma exacerbation were the guiding principles in the selection process of the participants. The studied sample consisted of students who acquired a disability due to the presence of anamnesis of injured, ankle, complex fractures, or knee injuries of only one limb and were recovered within half a year.

Table 1. Anthropometric data study participants

Number of participants	24
Age (years)	20.20±2.33
Height (cm)	178.15±6.04
Leg length	96.70±5.12
Weight (Kg)	72.70±7.18

A medical worker's permission to participate in the experiment was obtained for each participant of the studied sample. Students who voluntarily agreed to participate in the experiment provided informed written consent.

The study was planned and carried out following the principles of bioethics set forth by the World Medical Association (WMA–2013) in the Helsinki Declaration «Ethical Principles of Medical Research Involving Humans» and UNESCO in the “General Declaration on Bioethics and Human Rights”.

Methods

The research was carried out using methods of the theoretical (analysis, synthesis, generalization) and empirical (pedagogical experiment, pedagogical testing, methods of mathematical statistics) levels.

The choice of pedagogical testing methods is justified by the need to use several indicators that measure different parameters. This position is supported by evidence (Ivashchenko, 2020) that suggests that using multiple measures of outcome and assessment provides a more comprehensive understanding of all aspects of the recovery process (De la Motte, Lisman, Gribbin, Murphy, & Deuster, 2019).

Using research findings (Kim, & Kim, 2018; Wang, Yu, Zhang, Wang, & Chen, 2023; Picot, Terrier, Forestier, Fourchet, & Mc Keon, 2021), on balance factors that are recommended to be considered in the recovery process, we prepared a set of tests. The execution of the selected tests does not require complex equipment, is easy to reproduce, and at the same time allows the assessment of various aspects of the process of restoring the functions of the injured lower limbs.

The Star Excursion Balance Test (SEBT) is a dynamic test that requires strength, flexibility, and proprioception (Kaminski, & Gribble, 2003). SEBT was designed to be used as a rehabilitative tool for lower extremity pathologic conditions, the test can be used to screen deficits in dynamic postural control due to musculoskeletal injuries (e.g. chronic ankle instability) (Gribbl, Hertel, & Plisky, 2012). Test procedure. The person performing the test must maintain their balance on one leg, while using the other leg to reach as far as possible in 8 different directions (Fig. 1) (Star Excursion Balance Test).

The Single Leg Stance (SLS) рекомендуют (Sibley, Straus, Inness, Salbach, Jaglal, 2013) is used to assess static postural and balance control (Single_Leg_Stance_Test).

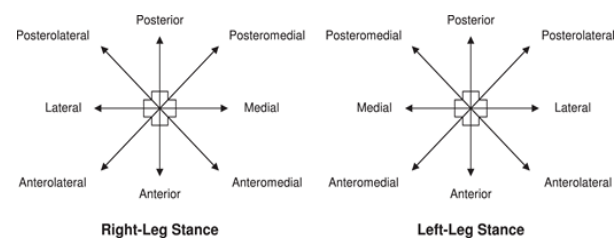


Fig. 1. Scheme of the SEBT (Gribbl, Hertel, & Plisky, 2012)

Performed with eyes open and hands on the hips. Student stands on one leg unassisted; time begins when opposite foot leaves the ground; time stops immediately when opposite foot touches the ground and/or when hands leave the hips (Single Leg Stance Test).

Weight-bearing lunge test (WBLT) was used to control the mobility of the ankle joint (Fig. 2). WBLT implemented the evaluation of the range of motion of dorsiflexion in the ankle joint by the inclinometer method (Cosby, & Hertel, 2011), according to which they control the appropriate amplitude in the ankle, the presence of limited mobility and the range of motion as a risk factor for injuries to the lower extremities during physical activity or any which movement and which are recommended for use in the assessment of ankle and foot injury (Hall, & Docherty, 2017).

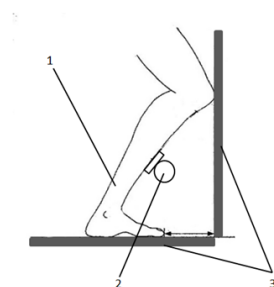


Fig. 2. Scheme of the WBLT: 1 –student, 2 – inclinometer, 3 – vertical and horizontal line

Test Procedure

This test needs to be done against a wall. A standard tape measure (cm) is necessary. Students are asked to place their feet in such a way that an imaginary line drawn through the heel and big toe is aligned on the tape measure on the floor. Furthermore, a vertical line is drawn on the wall in line with the tape measure. Students are instructed to lunge forward until their knee touches the wall (vertical line). The heel is required to remain in contact with the floor at all times. The foot is moved away from the wall to the point where the knee can only make slight contact with the wall, while the heel remains in contact with the floor. This puts the ankle joint in maximal dorsiflexion. The leg not being tested can rest on the floor and students are allowed to hold onto the wall for support. The maximum distance from the wall to the tip of the big toe is recorded (Weight-bearing lunge test).

Research Organization

To implement the experiment and achieve homogeneity of the studied sample, forms were prepared with the basic information of the participants of the studied sample, such as age, height, body weight, gender, and nature of injury. Before testing, all students were provided with clear instructions regarding the tests, the procedure for performing them and evaluating the results. After an appropriate warm-up, an opportunity was given to try to perform the test exercise three times, the average of three attempts was used in the analysis. Testing was implemented during two academic semesters at the beginning and at the end of the PE course.

Statistical Analysis

All statistical analyses were performed using SPSS Version 22.0 (IBM Corporation). The studied data were presented using the methods of descriptive statistics, the main one-dimensional variables were used: the value of the arithmetic mean ($\bar{X}$), standard deviation (S), median (Me), and coefficient of variation (V). Statistical significance was established using the Student's test, setting the level of significance at $p \leq 0.05$ (Myers, Well, & Lorch Jr, 2010).

Results

It should be noted that according to the data (Ursone, 2010), traumatic injuries of the limbs as a result of military actions differ in the mechanism of influence and consequences

on the body. At the same time, according to ideas (Bluman, & Ficke, 2010), the results of recovery after injury depend not only on treatment but also on complex physical rehabilitation with the formation of individual programs. Accordingly, as stated (Pellerin, Wilson, & Haegele, 2022), the current concept of inclusive PE involves a model that is primarily focused on the needs of each student with disabilities (Qi, & Ha, 2012).

Therefore, taking into account the above, and guided by information from literary sources, a PE program for students with disabilities due to injuries of the lower extremities was developed and tested. Here it was taken into account that, there are certain patterns according to which the lost functions are restored after injury to the lower extremities (Kisner, Colby, & Borstad, 2017).

The basis of the developed program was a differentiated approach to the definition of PE tactics, a comprehensive assessment of the achieved results, and the phasing of the implementation of modern approaches to optimize this process.

The priority of an individual flexible approach as an element of control over the recovery process became significant in the creation of the program (Rekaa, Hanisch, & Ytterhus, 2019). Special attention is focused on the prevention of the development of contractures in the joints of the limbs for the formation and assimilation of new motor skills (Beazell, Grindstaff, Sauer, Magrum, MIngersoll, & Hertel, 2012).

The program provides for timely correction based on indicators of control, which were used to systematically determine functional limitations in the lower extremities of students and monitor the effectiveness of the program (Snyder, Parsons, Valovich McLeod, Curtis Bay, Michener, & Sauers, 2008).

The effectiveness of the implementation of the program during the inclusive PE of students with disabilities due to injuries of the lower extremities is proven by the results of comparative control (Tab. 2). Qualitative assessment and mathematical-statistical processing of the results obtained after the end of the pedagogical experiment in the studied sample of students with disabilities provide the basis for a conclusion about the dynamics of shifts in the studied indicators, which are chosen as correlates of the recovery process after injuries of the lower extremities.

A significant improvement of indicators was found in all studied indicators without exception: according to the qualitative assessment of all studied parameters, it can be stated that after the end of the experiment, there is a general tendency to increase the results of the performance of test tasks.

The ability to maintain balance without support is a complex motor task, which has been observed to be significantly impaired when performing SLST with support on the injured limb. Despite the presence of positive dynamics in the test results, the results of the static and dynamic tests performed with support on the injured leg were significantly lower than with support on the uninjured leg ($p < 0.05$).

As a result, the average values of the results of the SLST based on the healthy limb moved into the range of values that are close to the normative averages. If at the beginning of the study, the performance of SLST with support on the injured limb was accompanied by significant difficulties, then at the end, along with the dynamics in the results, its performance did not cause significant stress to the participants of the studied sample.

Table 2. Results of test control

Statistical parameters		Test tasks and measurement results										
		at the beginning of the experiment					after of the experiment					
		X	S	As	Me	V	X	S	As	Me	V	effect,%
SEBT (sm) healthy limb	anterior	71.54	3.15	0.04	69.3	37.8	77.48	3.19	0.25	75.3	24.5	8.33
	anteromedial	73.33	5.8	0.04	73.3	22.3	81.2	3.55	0.47	80.6	25.9	10.71
	medial	77.18	5.3	0.68	77.01	32.7	85.6	5.9	0.63	84.3	34.1	10.96
	posteromedial	90.3	6.9	0.12	89.2	23.9	98.1	5.4	0.20	97.5	34.0	8.63
	posterior	88.7	3.51	0.51	88.1	33.4	99.9	5.9	0.01	99.1	27.9	12.62
	posterolateral	83.1	4.76	0.37	82.4	24.6	88.4	6.19	0.20	87.9	25.6	6.37
	lateral	69.41	4.23	0.38	1270	33.5	75.42	4.11	0.23	6.00	36.8	8.65
	anterolateral	72.76	4.11	0.42	70.02	35.7	80.1	3.8	0.65	79.3	23.4	12.13
SEBT (sm) injured limb	anterior	53.6	6.1	0.44	52.34	23.5	59.5	5.8	0.34	59.2	26.7	11.07
	anteromedial	55.90	4.04	0.25	54.12	29.0	62.93	5.3	0.14	62.23	33.6	12.57
	medial	60.34	5.15	0.15	60.01	27.9	71.55	5.9	0.52	70.49	33.0	18.05
	posteromedial	81.2	4.55	0.47	80.6	45.9	88.7	4.51	0.51	88.1	23.4	9.23
	posterior	76.61	3.97	0.36	6.11	43.4	84.3	4.5	0.62	85.0	28.4	10.03
	posterolateral	70.23	5.11	0.47	69.3	35.1	74.15	4.09	0.60	73.2	29.7	5.58
	lateral	59.15	4.1	0.06	58.67	40.4	68.28	3.08	0.35	38.32	33.5	15.43
	anterolateral	63.46	4.5	0.38	62.56	26.7	71.33	3.01	0.53	70.08	25.2	7.87
SLST (s)	injured limb	2.38	0.61	0.83	2.22	27.4	4.99	0.65	0.22	4.78	22.5	10.9
	healthy limb	9.01	1.02	0.53	8.99	27.2	23.0	3.11	4.62	21.3	26.7	15.27
WBLT	distance (sm)	8.6	2.33	3.17	21.1	25.1	12.1	3.16	0.48	9.95	23.5	4.69
	angle0	28.68	3.6	0.69	29.4	23.9	36.16	4.3	0.35	38.32	25.6	2.06

*The differences in the results at the beginning and after of the experiment are significant ($p < 0.05 - 0.001$)

The results of SEBT improved in all directions, the lowest indicators were recorded in the anterior direction, which is obviously determined by the increased risk of injury (Smith, Chimera, & Warren, 2015). The results of the SEBT of the injured limb are lower than the results of the healthy limb, which is natural since injuries of the lower extremities reduce the results of the SEBT (Picot, Terrier, Forestier, Fourchet, & Mc Keon, 2021).

The greatest increase in SEBT results was recorded in lateral distances (15.43 %), in the direction, the smallest in injured limb in posterolateral distances (5.58 %).

The results of WBLT showed an increase in the range of extension in the ankle joint, which, accordingly, affected an increase in the distance of posterior displacement of the ankle. If before the beginning of the study, the amount of ankle flexion was sufficient for normal walking, but indicated the risk of possible injuries (Matthew, Hoch, & McKeon, 2011), then at the end of the study, the index reached values that allow moving to more complex exercises. However, achieving average values requires further measures.

Discussion

The «degree» of the importance of restoring lost functions as a result of the injuries of students who received disabilities due to combat injuries significantly increased after the start of a full-scale war in Ukraine. Accordingly, the higher school, as a social institution, faces the task of creating the most possible favorable conditions for the implementation of the process of restoration of damaged functions in students with disabilities.

We agree with the opinion (Page, Anderson, & Charteris, 2021) that a prominent feature of inclusive PE, as a tool for ensuring the restoration of lost functions (Keles, ten Braak, & Munthe, 2022), is its dynamism (Kuntjoro, Soegiyanto, Setijono, & Suharto, 2022; Wolbring, & Lillywhite, 2021), because there is a constant modification of this process by the challenges of today (Blavt, Chaplinskyi, Prozar, Pityn, Helzhynska, Dmytruk, Hrebik, & Kovalchuk, 2023).

Our research is consistent with the information (Pocock, & Miyahara, 2018) that modern inclusive PE, as a means of restoring lost functions, requires the formation of modern content based on innovative pedagogical technologies. We support scientific approaches (Blavt, Iedynak, Pereverzieva, Holub, & Melnyk, 2023) that obtaining new scientific data on the recovery after war trauma of students with disabilities is a social need of Ukrainian society, which has especially gained importance recently, in connection with the full-scale invasion of Russia on the territory of Ukraine and prolonged hostilities.

Research is consistent with data (Lieberman, & Houston-Wilson, 2017; Goodwin, & Watkinson, 2020) that implementing a differentiated approach in PE is a powerful challenge, but this approach facilitates the process of inclusion (Pocock, & Miyahara, 2018; Kuntjoro, Soegiyanto, Setijono, & Suharto, 2022). The obtained research results correspond to experimental data (Blavt, & Gurtova, 2023), which prove the effectiveness of a differentiated approach in inclusive PE.

Our study extends the results of previous research that evidence of balance deficits, empirically quantified using foot and ankle capacity measurements, can be used as predictors

of the possibility of developing chronic ankle instability (Al-Mohrej, & Al-Kenani, 2016).

The need for urgent restoration of the functions of the lower limbs, which are affected after injuries, is due to the evidence (Beazell, Grindstaff, Sauer, Magrum, MIngersoll, & Hertel, 2012) that 20% of people develop the development of chronic ankle instability. This condition may be the result of a deficit in lower limb muscle strength and balance, or a possible impairment of postural control (Wang, Yu, Zhang, Wang, & Chen, 2023). Walking, jumping, occupational involvement, and physical activities can be affected (Snyder, Parsons, Valovich McLeod, Curtis Bay, Michener, & Sauers, 2008).

Our study is consistent with other empirical evidence that balance development declines with fitness level (Zhang, Talaber, Truong, & Vargas, 2019), and that increased ankle flexibility leads to an increase in dynamic balance control outcomes, namely distance to posterior reach distances (Seever, Mason, & Zech, 2022; Chaiwanichsiri, Lorprayoon, & Noomanoch, 2005). The results are consistent with the evidence regarding the strong correlation between flexor strength and posterior directions of the injured limb (Domingues, Serenza, Muniz, de Oliveira, Salim, Fogagnolo, Kfuri, & Ferreira, 2018); that dynamic balance deficits are observed in both injured and uninjured limbs when tested in selected directions of the SEBT (Doherty, Bleakley, Hertel, Caulfield, Ryan, & Delahunt, 2015); that a program aimed at the development of balancing on one leg helps to improve dynamic balance (Rasool, & George, 2007).

The conducted research is consistent with the evidence regarding the need for balance development as a condition for the success of the recovery process after acquired injuries, as lower extremity injuries reduce the effectiveness of SEBT (Picot, Terrier, Forestier, Fourchet, & Mc Keon, 2021). Accordingly (de la Motte, Lisman, Gribbin, Murphy, & Deuster, 2019), an insufficient level of balance indicates the presence of an injury of the lower extremities, and the dynamics of the development of balance, accordingly, provides information about the recovery process (Gribble, Hertel, & Plisky, 2012; Cimbiz & Bayazit, 2004).

The results of the conducted experiment confirm (Qi & Ha, 2012; Lieberman, & Houston-Wilson, 2017) that timely permanent control of the PE process is a factor in ensuring its effectiveness, which counteracts the development of complications due to injuries, or at least makes it possible to minimize the effects of negative the script

Conclusions

Currently, Ukraine has become the epicenter of extreme situations, when citizens suffer from Russian terrorist attacks for a long time. In the conditions of global challenges of the course of hostilities, both military personnel and representatives of the civilian population are equally at risk of receiving military injuries. Therefore, in institutions of higher education, there is a situation of a high percentage of students with disabilities due to war injuries.

The solution to the issue of restoration of functions of students with disabilities lost as a result of injuries to the lower limbs in the process of education can be seen in the development and implementation in practice of approaches

appropriate to the challenges of the time, which strengthen the practical potential for the organization and implementation of inclusive PE. An experimental study was conducted, the main purpose of which was to study the impact of the proposed innovations, which were implemented in the developed PE program, the main task of which was to restore the functions of the lower limbs of students with disabilities lost as a result of war injuries.

The obtained results of the final testing make it possible to state the effectiveness of the implemented program, as positive dynamics within 10-15% are observed for all the studied parameters. Statistically reliable positive dynamics of the set of investigated indicators proved that the implementation of the developed inclusive PE program for students with disabilities due to injuries of the lower extremities ensures the effectiveness of recovery due to functional injuries.

Conflicts of interest

No conflicts of interest exist.

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Інклюзивне фізичне виховання студентів з інвалідністю внаслідок травм війни: відновлення функцій нижніх кінцівок

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 2 табл., 2 рис., 49 джерел.

Історія питання. Актуальність дослідження обумовлена тим, що на заклади вищої освіти нині покладено завдання створити всі умови для відновлення втрачених внаслідок травмувань функцій організму та покращання стану здоров'я студентів з інвалідністю, що додатково актуалізує означену проблему в зв'язку з тривалими бойовими діями на території України.

Мета статті – виявити ефективність впливу розробленої програми інклюзивного фізичного виховання на відновлення втрачених функцій внаслідок травмувань нижніх кінцівок у студентів з інвалідністю.

Матеріали та методи. Для вирішення поставлених завдань використовували комплекс методів наукової розвідки на емпіричному та теоретичному рівні: аналіз літератури, спостереження, тестування, експеримент, методи математичної статистики. Тестову програму склали тести: балансу зіркової екскурсії, стійки на одній нозі та тест на випад із навантаженням. В експерименті взяли участь 24 здобувачі вищої освіти з інвалідністю чоловічої статі першого року навчання у закладі вищої освіти.

Результати. Згідно якісної оцінки отриманих результатів можна стверджувати, що після закінчення експерименту спостерігається загальна тенденція до зростання результатів виконання тестових завдань. Достовірне покращення показників виявлено у всіх без винятку досліджуваних параметрах: так як спостерігається позитивна динаміка в межах до 15 %. Попри наявність позитивної динаміки у підсумках, результати статичного і динамічного тесту з виконанням з опорою на травмованій нозі були значно нижчими, а ніж з опорою на неушкодженій нозі ($p < 0.05$).

Висновки. Отримані результати підсумкового тестування дають констатувати ефективність упровадженої програми. Статистично достовірною позитивною динамікою комплексу досліджуваних показників засвідчила, що реалізація розробленої програми інклюзивного фізичного виховання для студентів з інвалідністю внаслідок травм нижніх кінцівок, забезпечує ефективність відновлення ушкоджених функцій.

Ключові слова: інклюзія, фізичне виховання, здобувач вищої освіти з інвалідністю, травма війни.

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Analysis of Factors of Sports Migration and the Effectiveness of Competitive Activity of Football Players

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Abstract

The purpose of the work: determine the ways of correcting the training process based on taking in to account the influence of sports migration factors on the training of highly qualified football players.

Material and methods. To assess the impact of factors of sports migration on the effectiveness of competitive activity, the indicators of the competitive activity of football players of the national team of Ukraine in 16 official games during the 2020-2021 and 2021-2022 seasons. Methods of research. Analysis, generalization and systematization of data from scientific and methodological literary sources and the "Internet", pedagogical observations, content analysis of competition regulations (based on the materials of the official FIFA; UEFA; UAF sites), analysis of performance indicators of competitive activity; method of expert evaluations; methods of mathematical statistics.

Results. The 2020-2021 season: in 62,5% of official games, higher indicators were recorded for football players of the first group ("migrants" and "naturalized" athletes), the range of indicators – from 58.33% to 77.50%. At the same time, statistically significant differences (25.00%) were recorded in 2 games. In one game, higher indicators were recorded for football players of the first group ("migrants" and "naturalized" athletes) and, in one game, higher indicators were recorded for football players of the second group (athletes who were born in Ukraine are national athletes of the UAF and participate in UPL competitions). The 2021-2022 season: in 62.5% of official games, higher indicators were recorded for football players of the first group ("migrants" and "naturalized" athletes), the range of indicators – from 50.01% to 74.16%. No statistically significant differences were recorded. The comparative effectiveness of football players of the first and second groups was 46.15% and 53.85%, respectively.

Conclusion. This state of affairs indicates the need to correct the modern system of multi-year improvement of highly qualified football players based on the development and formation of technologies for the direct training of migrant athletes for official international competitions.

Keywords: football, highly qualified athletes, sports migration, training, competitive activity.

Introduction

Modern football is one of the most popular sports in the world. As of today, the international football federation (FIFA) has 211 collective members (official website of the FIFA). Official international competitions at the level of club and national teams – World Championships, club continental competitions arouse considerable interest of the general population and leading mass media. This stimulates the processes of competition between football players and teams,

which is one of the leading factors in the development of football in the global dimension.

Foreign scientists have repeatedly turned to consideration of problematic issues related to the influence of migration processes on the system of training football players. In particular, widely known studies (Poli, 2019; Poli, Ravenel & Besson, 2019a; Poli, Ravenel & Besson, 2019b), which are aimed at studying the influence of global factors (including sports migration) on the development of football. Research (Elliot, 2014; 2017; 2019) relate to the study of the mental prerequisites of sports migration in relation to the issues of training football players. Scientific explorations (Lago-Peñas, S. Lago-Peñas & Lago, 2019; Lago-Peñas, 2020) devoted to

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the issue of the influence of sports migration processes on the effectiveness of the competitive activity of “elite” football teams, that is, highly qualified football players.

One of the first thorough studies of the management system of long-term training of football players in Ukraine are the scientific works of researchers (Lisenchuk & Tyshchenko, 2019a; Lisenchuk & Tyshchenko, 2019b; Lisenchuk & Tyshchenko, 2020), which reveal the methodology of managing the educational and training process and competitive activities of football players of various ages and qualifications; contain special tests, qualitative and quantitative criteria for evaluating the special physical and technical and tactical preparedness of football players; allow formulating practical recommendations for optimizing the management system at various stages of preparation.

Subsequently, the specified scientific investigations received a logical continuation in a monograph (Shamardin, 2012) regarding the improvement of the management technology of the multi-year training system of highly qualified football teams; scientific studies (Nikolaenko, Maksymchuk, Donets et al., 2021; Nikolaenko, Vorobiov, Chopilko et al., 2021) regarding the improvement of the system of long-term training of football players to achieve higher sportsmanship; scientific research (Kostiukevych, Imas, Borysova et al., 2018; Kostiukevych, Lazarenko, Shchepotina et al., 2019; Kostiukevych, Shchepotina & Vozniuk, 2020) regarding the application of modeling methods and model characteristics of football players readiness in the process of their long-term improvement; scientific studies (I. Doroshenko, Svatyev, Sobol et al., 2023; I. Doroshenko, Svatyev, Sobol E. et al., 2023) regarding the optimization of management of technical and tactical activities of qualified football players. The specified scientific works are based on the general theory of sports, the system of training athletes and the theory of periodization of long-term sports improvement (Bubka, Bulatova, Esentaev et al., 2017), which constitute the background and fundamental basis of the specified scientific direction.

In addition, scientific research on the use of training technologies for athletes of different age groups is important for improving the training management system and increasing the efficiency of the competitive activity of football players (Mulyk, & Kraynik, 2019).

Research (Lyzohub, Pustovalov, Grechukha & Shpanyuk, 2018; Lyzohub, Pustovalov, Suprunovich et al., 2021) concerns the topical issues of selecting highly qualified football players based on indicators of bioenergetic metabolism and assessment the effectiveness of the competitive activity of football players depending on the quantitative and qualitative characteristics of neurodynamic functions.

At the same time, in recent years, a new scientific direction has been formed in the theory of long-term training in sports games. These are scientific studies (Imas & Borisova, 2017) that relate to the impact of certain global factors, in particular, commercialization and professionalization on the development of the game sports system in Ukraine (on the material of tennis); scientific intelligence (Sushko & Doroshenko, 2019), which is aimed at studying the factors of the development of game sports (based on the material of basketball) in the conditions of the influence of global factors on sports of higher achievements. First of all, it concerns issues of sports migration, commercialization and politicization of

official competitions, professionalization and socialization of athletes, etc. The specified scientific direction was continued in research (Sobol, Svatyev, Doroshenko et al., 2021; Sobol, Svatyev & Doroshenko et al., 2021a; Sobol, Svatyev & Doroshenko et al., 2021b; Sobol, 2022), which raise a wide range of problematic issues regarding the financial prerequisites for sports migration of highly qualified football players; compliance of the activities of professional football clubs with the criteria of financial “Fair Play”, the formation of innovative technologies for the training of highly qualified football players, taking into account the factors of sports migration. From this point of view, the relevant issues of taking in to account the level of quantitative and qualitative characteristics of the level of competitive practice of football players, the individualization of their direct preparation for official national and international competitions, the determination of the individual contribution of migrant football players to the overall team result, etc., are significant. The indicated directions indicate the need to correct the modern system of managing the long-term training of qualified athletes – on the one hand, the issue of sports migration requires the use of fundamentally different methodological approaches and technologies for improving the training process, on the other hand, the issue of improving football players who are pupils of national football schools is becoming more significant or the Academy.

At the present time, the mentioned problems have received initial development in the works of foreign and domestic scientists, but a number of fundamental questions regarding the regulatory norms of official competitions in the context of determining the rational ratio of migrant football players and national athletes in competitive activities, compliance by professional football clubs with the criteria of financial “Fair Play”, implementation of norms of national legislation to international criteria of “naturalization” of athletes, etc.

Hypothesis. The study of the influence of the factors of sports migration and their use in the training process will contribute to increasing the efficiency of the competitive activity of highly qualified football players.

The purpose of the work: determine the ways of correcting the training process based on taking in to account the influence of sports migration factors on the training of highly qualified football players.

Material and Methods

Study Participants

To assess the impact of factors of sports migration on the effectiveness of competitive activity, the indicators of the competitive activity of football players of the national team of Ukraine in 16 official games were used: 8 official games of the 2020-2021 season: group “D” of the UEFA qualification for the final tournament of the 2022 FIFA World Cup) and 8 official games of the 2021-2022 season (2 games of the play-off qualifying round for the 2022 FIFA World Cup final tournament and 6 UEFA Nations League B games of the 2022-2023 season). A total of 176 football players of the national team of Ukraine were analyzed during the 2020-2021 and 2021-2022 seasons.

Organization of the Study

Experimental research was carried out in coordination with experts of the Scientific-Methodological Council and Coach Licensing Center of the Ukrainian Football Association and members of the complex scientific group of the national football team of Ukraine. Materials from official websites were also used regarding the determination of indicators of sports migration in the starting lineups of the national team of Ukraine in the specified official matches (official website of the FIFA; official website of the UEFA; official website of the UAF).

Methods of Research

Analysis, generalization and systematization of data from scientific and methodological literary sources and the "Internet", pedagogical observations, content analysis of competition regulations (based on the materials of the official FIFA; UEFA; UAF sites), analysis of performance indicators of competitive activity; method of expert evaluations; methods of mathematical statistics.

Statistical Analysis

During the experimental study, the following calculated indicators were determined using mathematical statistics methods: arithmetic mean, percentage value, efficiency of competitive activity (according to the indicator of expert evaluations, ECA, formula 1), indicator of sports migration (ISM, formula 2).

$$ECA = \frac{e(n)\% \cdot 100\%}{n}, \quad (\text{formula 1})$$

ECA – efficiency of competitive activity, %; e – expert evaluation, %; n – number of experts;

$$ISM = \frac{m(n) \cdot 100\%}{11}, \quad (\text{formula 2})$$

ISM – indicator of sports migration, %; m(n) – number of migrant athletes in the team's starting lineup.

Results

In order to determine the impact of sports migration indicators on the effectiveness of the competitive activity of highly qualified football players – players of the national team of Ukraine in official matches of the 2020-2021, 2021-2022 seasons, indicators of the effectiveness of competitive activity and indicators of sports migration were determined (tables 1 and 2)

Based on the data in Table 1, we state that the effectiveness of the competitive activity of football players in the 2020-2021 season (before the introduction of the author's technology of direct preparation for competitions) was:

- number of wins, 2 out of 8 games (25%), draws – 6 out of 8 games (75%);
- ratio of scored and missed goals – 11:8 = 1,38; with an average performance per game – 1,38;
- number of points scored: 12 (on average per game – 1.5);
- the rate of migration in the starting lineups of teams in the range from 27.27% to 54.54% (the average rate of participation of "migrant" football players, and "naturalized" football players in the game is 38.63%).

Based on the data in Table 2, we state that the effectiveness of the competitive activity of football players in the 2021-2022 season (after the introduction of the author's technology of direct preparation of football players for competitions) was:

- number of wins, 4 out of 8 games (50%), with 2 draws (25%) and 2 losses (25%);

Table 1. Performance indicators of the competitive activity of football players in the 2020-2021 season, taking in to account the indicators of sports migration, n = 88

Official international competitions UEFA		Performance indicators of competitive activity and migration of football players		
date	national teams	score, points	ECA, %	ISM, %
24.03.21	France – Ukraine	1:1 (1:1)	77.50	-
			65.71	36.36
28.03.21	Ukraine – Finland	1:1 (1:1)	58.00	54.54
			59.38	-
31.03.21	Ukraine – Kazakhstan	1:1 (1:1)	62.50	45.45
			67.86	-
01.09.21	Kazakhstan – Ukraine	2:2 (1:1)	68.00	-
			63.38	45.45
04.09.21	Ukraine – France	1:1 (1:1)	66.25	27.27
			61.67	-
09.10.21	Finland – Ukraine	1:2 (0:3)	62.50	-
			62.08	27.27
12.10.21	Ukraine – B&H	1:1 (1:1)	60.50	27.27
			58.33	-
17.11.21	B&H – Ukraine	0:2 (0:3)	65.00	-
			70.63	45.45

Note: B&H – Bosnia and Herzegovina

Table 2. Performance indicators of the competitive activity of football players in the 2021-2022 season, taking in to account the indicators of sports migration, n = 88

Official international competitions UEFA		Performance indicators of competitive activity and migration of football players		
date	national teams	score, points	ECA, %	ISM, %
01.06.22	Scotland – Ukraine	1:3 (0:3)	74.16 72.22	– 45.45
05.06.22	Wales – Ukraine	1:0 (3:0)	67.50 66.00	– 45.45
08.06.22	Ireland – Ukraine	0:1 (0:3)	68.33 65.45	– 27.27
11.06.22	Ukraine – Armenia	3:0 (3:0)	71.50 70.00	27.27 –
14.06.22	Ukraine – Ireland	1:1 (1:1)	55.63 58.75	36.36 –
21.09.22	Scotland - Ukraine	3:0 (3:0)	50.01 50.84	– 36.36
24.09.22	Armenia – Ukraine	0:5 (0:3)	74.16 71.00	– 45.45
27.09.22	Ukraine – Scotland	0:0 (1:1)	57.50 57.00	63.63 –

- ratio of scored and missed goals – 13:6 = 2.17; with an average performance per game – 1.63;
- number of points scored: 14 (average per game – 1.75);
- the rate of migration in the starting list of teams in the range from 27.27 to 63.63% (the average rate of participation of “migrant” football players, and “naturalized” football players in the game is 40,91%).

In addition, a comparative pedagogical analysis of the indicators of the effectiveness of the competitive activity of football players of the national team of Ukraine was carried out with the differentiation of athletes into groups of football players, namely: the first group of football players who are “migrants” and “naturalized” athletes play in the Ukrainian Premier League (UPL); the second group of football players, who were born in Ukraine, are pupils of the UAF Youth Football Association and participate in UPL competitions.

Indicators of the effectiveness of the competitive activity of football players are determined by the method of expert evaluations with the involvement of specialists of the complex scientific group (CSG) of the national team of Ukraine, the Scientific- Methodological Council and Coach Licensing Center of UAF. On the basis of the obtained scientific results, we state that the performance indicators of the competitive activity of football players of the national team of Ukraine before 2020-2021 season and after the introduction of the original technology of direct training of football players for official competitions 2021-2022 season have the following dynamics:

- the 2020-2021 season: in 62,5% of official games, higher indicators were recorded for football players of the first group (“migrants” and “naturalized” athletes), the range of indicators – from 58,33% to 77,50%. At the same time, statistically significant differences (25,00%) were recorded in 2 games. In one game, higher indicators were recorded for football players of the first group (“migrants” and “nat-

uralized” athletes) and, in one game, higher indicators were recorded for football players of the second group (athletes who were born in Ukraine are national athletes of the UAF and participate in UPL competitions). This applies to matches: 24.03.21, France – Ukraine – 1:1 and 17.11.21, Bosnia and Herzegovina – Ukraine – 0:2, respectively. The comparative effectiveness of football players of the first and second groups was 70% and 30%, respectively (with one own goal);

- the 2021-2022 season: in 62,5% of official games, higher indicators were recorded for football players of the first group (“migrants” and “naturalized” athletes), the range of indicators – from 50,01% to 74,16%. No statistically significant differences were recorded. The comparative effectiveness of football players of the first and second groups was 46,15% and 53,85%, respectively.

Discussion

The results of the obtained experimental studies indicate that the modern system of long-term training of highly qualified football players needs significant correction. In this context, the issues of substantiation, development and formation of the technology of direct training of football players for official competitions of the national and international levels, taking in to account migration factors, are significant. It is necessary to take in to account the indicators of various types of long-term improvement, the characteristic features of non-training, non-competition factors, the influence of migration processes on the training system (level competitive practice and performance of “migrant” and “naturalized” football players). It is also significant to take in to account issues that are directly related to the material, technical and financial and economic support for the development of football – the national gross domestic profit, the current

legislative framework, the presence or absence of military conflicts on the territory of the country, financing of the field of physical culture and sports, amateur and of professional football clubs, the current demographic situation (population, number of people involved in football at the children's and youth, amateur, professional levels, etc.), the state of the material and technical base of football clubs and the state of the relevant accompanying infrastructure (transport, hotel, food, medical rehabilitation, etc.).

The above allows us to state that as a result of the conducted experimental studies, modern approaches to the development of new scientific directions have been formulated, which relate to the following topical issues:

- for the first time, the necessity of correcting the modern system of long-term sports training of football players, taking in to account the factors of sports migration, was substantiated;
- improved scientific data on the processes of managing the long-term training of football players, taking in to account global factors (including sports migration (Kostiukevich, Doroshenko, Sushko et al., 2023; Lisenchuk, Khmelnitska, Kokareva et al., 2021; Shchepotina, Kostiukevych, Asauliuk et al., 2021);
- directions and ways of improving long-term training as a component of the general theory of sports and the system of training athletes have gained further development (Zhurid, 2017; Kokareva, Kokarev, Doroshenko, 2018; Kokareva, Doroshenko, Kokarev, Danylchenko, 2021).

Prospects for further research are based on detailing ways to improve the management system of multi-year sports training of football players of different age groups, gender and qualification categories based on taking in to account the influence of sports migration factors. Also promising, in our opinion, is periodic monitoring of regulatory norms for admission to competitions of football players ("migrants" and "naturalized" athletes) and national UAF athletes.

Conclusions

The analysis of scientific and methodological literature, information sources of the "Internet" network and the results of own experimental research allows us to ascertain the existence of interrelationships between the factors of sports migration and the effectiveness of the competitive activity of highly qualified football players.

This state of affairs indicates the need to correct the modern system of multi-year improvement of highly qualified football players based on the development and formation of technologies for the direct training of migrant athletes for official international competitions.

The basis of this technology should be the following components:

- the composition of the team of a professional football club for official national or international competitions; registration of players taking in to account the factors of sports migration: football players are "migrants" or "naturalized" athletes, pupils of the national association's youth sports academy;
- specialized component technologies: individualization of training of football players, selective integra-

tion of individual types of training, special analysis of indicators of training and competitive activity; differentiation of team composition into typological groups: starting composition, application (protocol) composition for the game, extended team composition, close reserve; accounting of quantitative and qualitative indicators of competitive practice in accordance with its levels: regional, national, international competitions, educational and bilateral games, control and friendly games.

Conflict of interest

The authors state no conflict of interest.

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Аналіз факторів спортивної міграції та ефективності змагальної діяльності футболістів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 2 табл., 2 рис., 49 джерел.

Мета роботи: визначити шляхи корекції тренувального процесу на основі врахування впливу факторів спортивної міграції на підготовку висококваліфікованих футболістів.

Матеріал і методи. Для оцінки впливу чинників спортивної міграції на ефективність змагальної діяльності проаналізовано показники змагальної діяльності футболістів національної збірної команди України в 16 офіційних іграх протягом сезонів 2020-2021 та 2021-2022 років. Методи дослідження. Аналіз, узагальнення та систематизація даних науково-методичних літературних джерел та мережі «Інтернет», педагогічні спостереження, контент-аналіз регламентних документів змагань (за матеріалами офіційних сайтів ФІФА; УЄФА; УАФ), аналіз показників ефективності змагальної діяльності; метод експертних оцінок; методи математичної статистики.

Результати. Сезон 2020-2021 рр.: у 62,5% офіційних ігор вищі показники зафіксовано у футболістів першої групи («мігранти» та «натуралізовані» спортсмени), діапазон показників – від 58,33% до 77,50%. При цьому статистично значущі відмінності (25,00%) були зафіксовані у 2 іграх. В одній грі вищі показники зафіксовано у футболістів першої групи («мігранти» та «натуралізовані» спортсмени) та, в одній грі, вищі показники зафіксовано у футболістів другої групи (спортсмени, які народилися в Україні, є національними спортсменами УАФ та беруть участь у змаганнях УПЛ). Сезон 2021-2022 рр.: у 62,5% офіційних ігор вищі показники зафіксовано у футболістів першої групи («мігранти» та «натуралізовані» спортсмени), діапазон показників – від 50,01% до 74,16%. Статистично значущих відмінностей не зафіксовано. Порівняльна ефективність футболістів першої та другої груп склала 46,15% та 53,85% відповідно.

Висновок. Такий стан справ свідчить про необхідність корекції сучасної системи багаторічного вдосконалення висококваліфікованих футболістів на основі розробки та формування технологій безпосередньої підготовки спортсменів-мігрантів до офіційних міжнародних змагань.

Ключові слова: футбол, висококваліфіковані спортсмени, спортивна міграція, підготовка, змагальна діяльність.

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Discriminant Analysis: the Influence of Exercise Modes on the Effectiveness of the Process of Learning to Throw A Small Ball for 9-Year-Old Boys

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

The purpose of the study is to determine the effect of the number of repetitions on the effectiveness of the process of learning to throw a small ball for 9-year-old boys.

Materials and methods. The study involved 27 9-year-old boys, divided into three groups of 9 people in random order. Children and their parents were aware of all the features of the study and gave consent to participate in the experiment.

The influence of the number of repetitions on the effectiveness of the process of learning to throw a small ball at a target in 9-year-old boys was studied. In a pedagogical experiment, the effect of 6, 12 and 18 repetitions with a rest interval of 60 s on the increase in the level of training in exercises of 9-year-old boys was studied. In the first group, boys repeated the task 6 times with a rest interval of 60 s, in the second group – 12 times with a rest interval of 60 s, in the third group 18 times with a rest interval of 60 s. In the process of teaching throwing exercises in a lesson, the level of training (“completed”, “failed to complete”) was assessed using an alternative method, and the probability of completing the exercise was calculated ($p = n/m$, where n is the number of successfully completed attempts, m is the total number of attempts).

The method of algorithmic prescriptions was used in teaching 9-year-old boys. The transition to the next exercise was carried out after three successful attempts. Throwing a ball at a vertical target was studied.

The research materials were processed in the statistical analysis program – IBM SPSS 20. In the process of discriminant analysis, a prognostic model for group membership was created.

Results. Discriminant analysis made it possible to determine the influence of the number of repetitions on the effectiveness of developing the skills of throwing a small ball at a target; answer the question how reliably the repetition modes differ in terms of the effectiveness of the formation of motor skills, what class the object belongs to based on the discriminant values of the variables.

Conclusions. Based on the analysis of group centroids, it was determined that 18 repetitions (6 sets of 3 times with a rest interval of 60 s) has a significant impact on the increase in the level of learning in physical education lessons. The group classification results show that 63.0% of the original grouped observations were correctly classified.

Keywords: 9-year-old boys, ball throwing, discriminant analysis.

Introduction

The problem of developing motor skills in schoolchildren was considered in the context of gender characteristics of motor readiness (Ivashchenko, Nosko, Bartik, & Makanin, 2020), determining the priority of developing motor skills in the process of physical education (Shevchenko, Khudolii, &

Potop, 2020; Petrov, Khudolii, & Cieślicka, 2020; Khudolii, Golovnin, & Bartík, 2020), the influence of physical exercise regimes on the effectiveness of motor skills formation (Ivashchenko, 2020; Ivashchenko, Iermakov, Khudolii, Cretu, & Potop, 2017; Ivashchenko, Holovko, 2015), the influence of training loads on dynamics of strength development (Khudolii, Ivashchenko, & Beketov, 2015; Ivashchenko, & Cieślicka, 2017; Cieślicka, & Ivashchenko, 2017).

The formation of motor skills in schoolchildren is a necessary condition for optimizing motor activity and improv-

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ing their health (Barnett, Hardy, Lubans, Cliff, Okely, Hills, & Morgan, 2013; Chan, Ha, & Ng, 2016; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Research indicates the importance of developing children's skills in performing exercises with a ball Mathisen (2016), Nurulfa, Lubis, Dlis, Aninggar, and Mamesah (2021), Fernández-Valero, Soto-Sánchez, Páez, Leyton-Dinamarca, Kain, Hurtado, and Reyes-Amigo (2021).

Important in obtaining objective results about the patterns of the learning process is planning an experiment and using multivariate statistics. The effectiveness of discriminant analysis in studying the patterns of the learning process of children and adolescents has been established (Medko & Khudolii, 2021; Marchenko et al., 2021, 2022; Yunak, Ivashchenko, Nosko, & Nosko, 2022). Consequently, the use of discriminant analysis will allow us to obtain new information about the age-related characteristics of the formation of basic motor skills in primary schoolchildren.

In connection with the need to increase the physical activity of children, research into the effectiveness of the learning process for schoolchildren is relevant.

The purpose of the study is to determine the effect of the number of repetitions on the effectiveness of the process of learning to throw a small ball for 9-year-old boys.

Materials and Methods

Study Participants

The study involved 27 9-year-old boys who were randomly divided into three groups of 9 people. The children and their parents were aware of all the features of the study and gave consent to participate in the experiment.

Organization of the Study

The influence of the number of repetitions on the effectiveness of the process of learning to throw a small ball at a target in 9-year-old boys was studied.

In a pedagogical experiment, the effect of 6, 12 and 18 repetitions with a rest interval of 60 s on the increase in the level of training in exercises of 9-year-old boys was studied. In the first group, boys repeated the task 6 times with a rest interval of 60 s, in the second group – 12 times with a rest interval of 60 s, in the third group 18 times with a rest interval of 60 s.

In the process of learning throwing exercises in a lesson, the level of training ("completed", "failed to complete") was assessed using an alternative method, and the probability of completing the exercise was calculated ($p = n/m$, where n is the number of successfully completed attempts, m is the total number of attempts).

The method of algorithmic prescriptions was used in teaching 9-year-old boys. The transition to the next exercise was carried out after three successful attempts. Throwing a ball at a vertical target was studied.

Statistical Analysis

The work used well-known methods for analyzing the results of a full factorial experiment of type 2k (Khudolii & Ivashchenko, 2014; Ivashchenko, 2016).

The research materials were processed in the statistical analysis program – IBM SPSS 20. In the process of discriminant analysis, a predictive model for group membership was created. This model constructs a discriminant function (or, when there are more than two groups, a set of discriminant functions) as a linear combination of predictor variables, which provides better separation of groups. These functions are constructed from a set of observations for which their group membership is known. These functions can then be applied to new observations with known values of predictor variables and unknown group membership.

For each canonical discriminant function, the following were calculated: value, percentage of variance, canonical correlation, Wilks' Lambda, χ -square (Chi-square).

To determine the impact of the proposed physical exercise regimens for 7-year-old boys, a discriminant analysis was carried out. The influence of the number of approaches, the number of repetitions in an approach and the rest interval on the level of training in the following movements was analyzed: 1. Throws of a ball on the floor; 2. Throws of a ball forward and upward with feet shoulder width apart; 3. Throws of a ball forward and up, left foot forward; 4. Throws of a ball forward and upward with the left side towards the throwing side; 5. Throws of a ball at the target from a distance of 3 m.

The study protocol was approved by the Ethics Committee of the educational institution. In addition, children and their parents or legal guardians were fully aware of all features of the study, and a signed informed consent document was obtained from all parents.

Results

To determine the influence of different modes of physical exercise on the level of training, a discriminant analysis was carried out (see Tables 1-4).

The first canonical function explains the variation of results by 96.9%, which indicates high information content ($r=0.662$) (see Table 1). Materials from the analysis of canonical functions indicate the statistical significance of the first and second canonical functions ($\lambda_1=0.549$; $p_1=0.05$; $\lambda_2=0.976$; $p_2=0.970$). The first function has a high discriminant ability and significance in interpretation relative to the general population (Table 2).

Table 3 shows the normalized coefficients of the canonical discriminant function, which allow us to determine the

Table 1. Canonical discriminant function. Eigenvalues. Boys 9 years old

Function	Eigenvalues	% of explained variance	Cumulative %	Canonical correlation
1	0.779	96.9	96.9	0.662
2	0.025	3.1	100.0	0.155

Table 2. Canonical discriminant function. Wilks' Lambda. Boys 9 years old

Checking functions	Wilks' Lambda	Chi-square	degrees of freedom	p
from 1 to 2	0.549	13.210	10	0.050
2	0.976	0.538	4	0.970

Table 3. Coefficients of the canonical discriminant function. Wilks' Lambda. Boys 9 years old

No	Exercise	Normalized coefficients		Structural coefficients	
1	Throws of a ball on the floor	0.751	0.141	0.551*	0.161
2	Throws of a ball forward and upward with feet shoulder width apart	0.418	0.828	0.125	0.859*
3	Throws of a ball forward and up, left foot forward	0.293	-0.022	0.212*	0.046
4	Throws of a ball forward and upward with the left side towards the throwing side	0.144	-0.414	0.156	-0.383*
5	Throws of a ball at the target from a distance of 3 m	0.840	-0.209	0.535*	-0.521

ratio of the contribution of variables to the result of the function. The variables with the greatest contribution to the first canonical function include variables No. 5 "Throws of a ball at the target from a distance of 3 m", No. 1 "Throws of a ball on the floor", the second canonical function includes exercise No. 2 "Throws of a ball forward and upward with feet shoulder width apart": the greater the increment in the learning ability of these exercises, the greater the importance of the functions. The above indicates that exercises No. 5, 1, 2 are most sensitive to the number of repetitions in 9-year-old schoolchildren.

Table 3 shows the structural coefficients of the canonical discriminant function, which are the correlation coefficients of the variables with the function. Thus, the function is most significantly related to the results of an increase in exercise learning No 1 "Throws of a ball on the floor", No 5 "Throws of a ball forward and upward with feet shoulder width apart", No 2 "Throws of a ball forward and upward with feet shoulder width apart": therefore, a significant difference between training modes is observed in exercises No. 1, 5, 2.

Table 4 shows the centroid coordinates for the two groups. They allow the canonical function to be interpreted in relation to its role in classification. On the positive pole is the centroid for the exercise mode of 18 repetitions, on the negative pole is the centroid for the exercise mode of 6 repetitions (see Figure 1). This indicates a significant difference in the influence of the number of repetitions on the increase in the level of learning in physical education lessons. The group classification results show that 63,0% of the original grouped observations were correctly classified.

Table 4. Functions in group centroids. Boys 9 years old

Options for operating modes	Function	
	1	2
6 reps, 60 s rest	-0.990	-0.113
12 reps, 60 s rest	-0.056	0.209
18 reps, 60 s rest	1.046	-0.096

Discussion

It is assumed that it is possible to use a discriminant function to assess the effectiveness of various modes of performing physical exercises in the process of training a series of throwing exercises, since the verification of canonical functions indicates their statistical significance.

Based on the analysis of group centroids, it was determined that 18 repetitions (6 sets of 3 times with a rest interval of 60 s) has a significant impact on the increase in the level of learning in physical education lessons. Group classification results show that 63,0% of the original grouped observations were classified correctly.

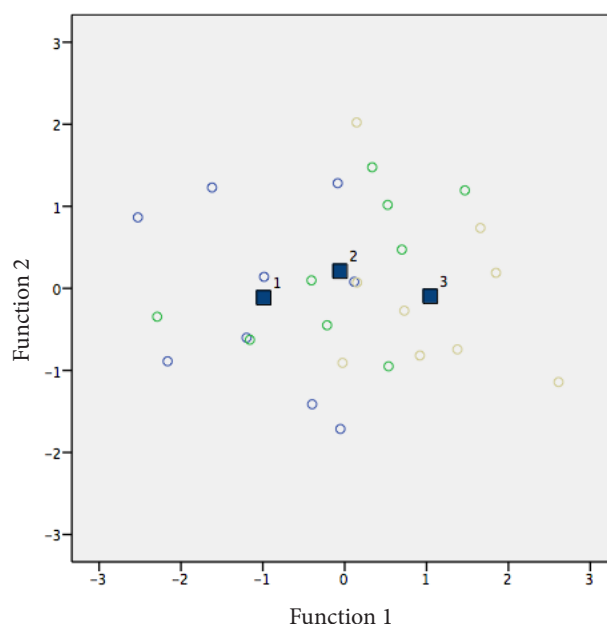


Fig. 1. Canonical discriminant functions. Graphic display of the results of classification of the level of training in exercises of 9-year-old boys: ■ — centroids for data groups after 1 – 6 repetitions, 2 – 12 repetitions, 3 – 18 repetitions

The data obtained complement the information on the influence of exercise regimes on the formation of motor skills in children (Ivashchenko, 2020; Ivashchenko, Iermakov, Khudolii, Cretu, & Potop, 2017; Ivashchenko, Khudolii, Iermakov, Chernenko, & Holovko, 2015; on the effectiveness of using the method algorithmic prescriptions for the formation of motor skills (Ivashchenko, 2020; Yunak et al., 2022; Marchenko et al., 2022), and also confirm data on the effectiveness of using discriminant analysis to optimize the process of physical education of schoolchildren (Samanta & Mukherjee, 2021; Djordjevic, Valkova, & Petkovic, 2021; Begu, Miftari, Dalip, & Haxhnikaj, 2023).

The results of the study can be used in the process of planning regimes for performing physical exercises in teaching manipulative motor skills to children of primary school age, which will improve the effectiveness of teaching fundamental motor skills and will help increase their motor activity.

Conclusions

Discriminant analysis made it possible to determine the influence of the number of repetitions on the effectiveness of developing the skills of throwing a small ball at a target; answer the question how reliably the repetition modes differ

in terms of the effectiveness of the formation of motor skills, what class the object belongs to based on the values of the discriminant variables.

Based on the analysis of group centroids, it was determined that 18 repetitions (6 sets of 3 times with a rest interval of 60 s) has a significant impact on the increase in the level of learning in physical education lessons. Group classification results show that 63,0% of the original grouped observations were classified correctly.

Conflict of interest

The authors declare that there is no conflict of interest.

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Дискримінантний аналіз: вплив режимів виконання вправ на ефективність процесу навчання метання малого м'яча хлопчиків 9 років

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 5 с., 4 табл., 1 рис., 23 джерела.

Мета дослідження – визначити вплив кількості повторень на ефективність процесу навчання метання малого м'яча хлопчиків 9 років.

Матеріали і методи. У дослідженні прийняли участь 27 хлопчиків 9 років, які були розділені на три групи по 9 чоловік у випадковому порядку. Діти та їхні батьки були інформовані про всі особливості дослідження і дали згоду на участь в експерименті.

Досліджувався вплив кількості повторень на ефективність процесу навчання метання малого м'яча в ціль у хлопчиків 9 років. У педагогічному експерименті вивчався вплив 6, 12 і 18 повторень з інтервалом відпочинку 60 с на приріст рівня навченості вправ хлопчиків 9 років. У першій групі хлопчики повторювали завдання 6 разів з інтервалом відпочинку 60 с, у другій групі – 12 разів з інтервалом відпочинку 60 с, у третій групі 18 раз з інтервалом відпочинку 60 с. У процесі навчання кидкових вправ у занятті оцінювався альтернативним методом рівень навченості («виконав», «не виконав»), розраховувалася вірогідність виконання вправи ($p = n/m$, де n – кількість успішно виконаних спроб, m – загальна кількість спроб).

У навчанні хлопчиків 9 років використовувався метод алгоритмічних розпоряджень. Перехід до наступної вправи здійснювався після трьох успішних спроб. Вивчалися метання м'яча у вертикальну ціль.

Матеріали дослідження опрацьовані в програмі статистичного аналізу – IBM SPSS 20. У процесі дискримінантного аналізу була створена прогностична модель для належності до групи.

Результати. Дискримінантний аналіз дозволив визначити вплив кількості повторень на ефективність формування навичок метання малого м'яча в ціль; дати відповідь на питання наскільки достовірно різняться режими повторення за результативністю формування рухових навичок, до якого класу належить об'єкт на основі значень дискримінантних змінних.

Висновки. На основі аналізу центротидів груп визначено, що 18 повторень вправи (6 підходів по 3 рази з інтервалом відпочинку 60 с) має суттєвий вплив на приріст рівня навченості на уроках фізичної культури. Результати класифікації груп показують, що 63,0 % вихідних згрупованих спостережень класифіковано вірно.

Ключові слова: хлопчики 9 років, метання м'яча, дискримінантний аналіз.

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Growth Mindset Training for Teacher: Method of Changing the Teacher's Mindset

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Abstract

Background. The academic success of students in schools is significantly shaped by their mental attitudes, especially when they face challenging situations that demand substantial effort and resilience. The influence of teachers' attitudes, or mindsets, plays a crucial role within the educational environment, as these directly impact students' own mindsets and subsequently their approach to learning. Specifically, the concept of a 'growth mindset' – which is the belief that one's abilities and intelligence can be developed through dedication and perseverance – has been shown to transform how individuals perceive their capabilities and respond to failures.

Objectives. In light of this, a specific study was conducted to evaluate the effectiveness of 'Growth Mindset Training' targeted at teachers. This training aimed to cultivate a growth mindset among educators, hypothesizing that a shift in teacher attitudes would, in turn, positively affect their students.

Materials and methods. To assess the impact of the training, researchers utilized a growth mindset scale to measure the mindsets of 19 participating teachers, comprising 11 women and 8 men, both before and after they underwent the training program.

Results. The findings from this study were quantitatively robust, with a T-statistic of -3.529 and a significance level of less than .005, indicating a statistically significant improvement in the teachers' growth mindsets post-training. Additionally, the analysis of mean scores from the pretest and posttest further confirmed an upward trend, suggesting that the mindset of the teachers had indeed shifted towards a more growth-oriented perspective.

Conclusions. Thus, Growth Mindset Training emerged as a potent intervention tool, not merely altering teachers' perceptions but potentially setting a foundation for enhancing the overall educational experience by fostering a culture of perseverance and continuous improvement in schools.

Keywords: educational psychology, teacher development, mindset transformation, student achievement.

Introduction

The shift to online education during the COVID-19 pandemic has notably altered the landscape of student engagement, where decreases in motivation and heightened stress levels have had a noticeable effect on their academic outcomes (Agustina et al., 2021; Astuti et al., 2021; Meeter et al., 2020; Zurriyati & Mudjiran, 2021). This transition has not only impacted students but also teachers, who have faced increased job-related stress, affecting their performance and well-being (Anita et al., 2021; Fauzan et al., 2022). The challenges posed by remote learning have necessitated a reevaluation of educational practices, prompting schools and educators to explore and implement a variety of innovative teaching tools and

methods. Among these are interactive platforms like Kahoot (Sinaga et al., 2022), engaging classroom activities such as Index Card Match (Zahwa & Erwin, 2022), digital resources like Wordwall (Permana & Kasrman, 2022), and collaborative learning strategies like the Cooperative Type STAD (Anwar et al., 2022), which have all been deployed to enhance the effectiveness and adaptability of educational delivery during these unprecedented times.

In the current phase of the New Normal, the Indonesian government has authorized the recommencement of in-person classroom sessions, a decision facilitated by the declining number of COVID-19 cases and the high vaccination rates among the public. Nonetheless, the transition back to physical classrooms has not been without its difficulties, particularly in the realm of educational adaptation. Students have been facing challenges such as a lack of motivation

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and a diminished interest in learning activities, highlighting significant adaptation issues (Sari, 2022). Studies have also shown that there is a pronounced effect of academic stress on students as they adjust to the limited face-to-face learning environments typical of the New Normal era (Siregar, 2022). These challenges emphasize the critical need for innovative educational strategies that address and enhance the face-to-face learning experience, ensuring that it is effective and responsive to the needs of students during these transitional times (Widyanigrum et al., 2022).

The concept of a Growth Mindset is a powerful tool to elevate student engagement and motivation for learning. By internalizing a Growth Mindset, students actively participate in their educational experiences, which in turn increases their cognitive awareness and interaction within their academic environments (Zhao et al., 2021). Crucially, the effectiveness of instilling a Growth Mindset in students largely depends on educators' attitudes and approaches (Mesler et al., 2021; Yu et al., 2022). Teachers' mindsets play a vital role in shaping their teaching strategies and responses to pedagogical challenges (Rissanen et al., 2018). The resilience of teachers during difficult situations, guided by their Growth Mindsets, often sets a precedent for students, showing them that perseverance is key to overcoming obstacles (C. Dweck, 2014).

Students who adopt and maintain a Growth Mindset tend to enhance not only their own learning experiences but also contribute positively to the learning environment, encouraging both fellow students and teachers to persist through challenges (Schmidt et al., 2017; Herdian & Rahayu, 2022; Nastiti et al., 2022). This proactive approach can significantly influence their mental health and overall well-being within the school setting (Herdian, Wahidah, et al., 2021; Wahidah & Royanto, 2019a). Research specifically conducted by Herdian et al. (2021) during the COVID-19 pandemic highlighted that students generally exhibited a moderate level of Growth Mindset, suggesting there is substantial room for enhancement. To effectively foster a more robust Growth Mindset, structured training programs have proven to be beneficial. These programs, as documented in studies, lead to notable improvements in both students' and teachers' mindsets before and after participation (Wahidah et al., 2022), demonstrating the transformative power of well-designed Growth Mindset interventions.

Based on insights from prominent researchers, Angela Duckworth (2016) characterizes the Growth Mindset as the perception an individual holds about their cognitive capacities, viewing these abilities as either static or expandable. Carol Dweck and her colleagues (2011) further elaborate on this concept, explaining that Growth Mindset involves an individual's commitment to the belief in their continuous ability to learn and excel, thereby anticipating advancements in their capabilities beyond their present scope. According to Bungsu and Rosadi (2021), a developing mindset is essentially a collection of beliefs that significantly affect a person's actions and attitudes, ultimately influencing their success in life. Suriyanti (2020) portrays Growth Mindset as inherently positive, suggesting that such an outlook leads to ongoing personal development. She argues that this positive mindset can be cultivated through specific therapeutic techniques that can be taught through structured training and environmental interactions. Farok and Mahmud (2020) describe Growth

Mindset as reflecting individuals who firmly believe that their limitations or failures are not merely due to innate deficiencies but are aspects that can be continuously developed, refined, and improved with persistent effort and holistic educational experiences.

The concept of Growth Mindset is crucial not just for fostering academic and personal growth but also as a dynamic tool within the educational process, beneficial for both students and educators (Uluduz & Gunbayi, 2020). This perspective is supported by Iskandar (2008), who asserts that educational environments play a crucial role in shaping an individual's learning journey. The regulations, as well as the behavior and attitudes of educators within schools, are instrumental in nurturing and enhancing already established mindsets, enriching the educational experience and encouraging a culture of continuous personal and intellectual growth.

To bolster the development of growth mindsets among educators, it is crucial to employ specialized training programs aimed at fostering these perspectives. Currently, there is a scarcity of empirical studies that utilize experimental approaches to evaluate the impacts of growth mindset training tailored for teachers. This research specifically targets the efficacy of such training programs in enhancing the growth mindset attributes of educators. Although there have been similar studies in the past, like those highlighted by Wahidah et al. (2022), there is a notable deficiency in research that focuses on teachers who identify with the Islamic faith. The primary objective of this study is to rigorously assess how Growth Mindset Training for Teachers can effectively improve the growth mindset of these educators, with an emphasis on understanding how these outcomes can vary across different cultural and religious teacher communities. This expanded focus will help in tailoring growth mindset interventions that are culturally sensitive and more universally applicable.

Materials and Methods

This research employs a quantitative experimental methodology, specifically using a quasi-experimental design due to its non-randomized nature. Such a design is chosen to facilitate direct comparisons that help deduce the effect of specific interventions (Hastjarjo, 2019). This study's structure is centered around a single group of participants without a control group, focusing on investigating the causal impacts of Growth Mindset Training for Teachers. The evaluation involves comparing the growth mindset scores from before and after the training, assessing how this professional development influences the teachers' attitudes and approaches.

Participant

The participants of this study include 19 teachers from an Islamic junior high school, comprising 11 women and 8 men. The age range of these participants spans from 24 to 56 years (Mean=35.79, SD= 12.45) showcasing a broad spectrum of life experiences. These teachers have varied lengths of service in education, ranging from as little as one year to as much as 33 years, reflecting a diverse group in terms of both age and professional experience. The specifics of the participant

demographics are summarized in the table below, which illustrates the wide array of backgrounds and the depth of teaching experience among the study's participants.

Table 1. Participant profile

Subject	Age	Sex	Length of work (years)
Participant 1	27	Female	1
Participant 2	26	Female	1
Participant 3	27	Female	1
Participant 4	58	Male	5
Participant 5	56	Male	27
Participant 6	26	Male	4
Participant 7	52	Male	18
Participant 8	38	Male	1
Participant 9	34	Female	1
Participant 10	32	Female	10
Participant 11	33	Male	5
Participant 12	31	Male	1
Participant 13	53	Female	33
Participant 14	24	Female	1
Participant 15	25	Female	1
Participant 16	59	Female	20
Participant 17	24	Female	1
Participant 18	30	Female	1
Participant 19	25	Male	1

This detailed participant information not only enriches the research data but also underscores the complexity and variability of the educational environment in which these teachers operate. By understanding this diversity, the study aims to provide richer insights into how growth mindset training can be tailored and implemented across varied educational settings, ultimately enhancing teacher efficacy and student outcomes.

Measurement

The Growth Mindset Scale is used to measure the level of growth mindset as a tool for both pretest and posttest assessments. This scale was developed by Wahidah and Royanto (2019) and is based on various aspects of the Growth Mindset as defined by Dweck (2006), which include: the belief in the development of intelligence, talents, and character; the belief that challenges, difficulties, and failures can foster personal growth; the belief in the value of effort and hard work; and the belief that criticism and feedback from others are essential for success. An example of an item on this scale is "I can develop myself to be more positive." The responses are scored using a Likert scale ranging from 1 (Strongly Disagree) to 4 (Strongly Agree) for favorable statements, and inversely for unfavorable statements, from 4 (Strongly Disagree) to 1 (Strongly Agree), comprising a total of 20 items. A cumulative score is calculated by summing the responses to these five items, with higher scores indicating a stronger growth

mindset. The Growth Mindset Scale has been validated and found reliable (Herdian & Rahayu, 2022). Data analysis for this research employs a Paired Sample t-test using the JAMOVI software program.

Procedure

Teachers volunteered to participate in the training program and completed a consent form to confirm their willingness to participate, with an assurance that all data collected would be confidential and used solely for research purposes. The training began with the administration of a pretest using the growth mindset scale. Subsequently, the participants underwent a comprehensive growth mindset training tailored for educators, structured into several segments.

The first part of the training focused on "brain plasticity," designed to help teachers understand how the brain's adaptability plays a crucial role in learning and development. The second segment delved into different types of mindsets and their impact on student motivation when facing challenges. The third part concentrated on the role of teachers in fostering a growth mindset among students, emphasizing the influence of teacher attitudes and behaviors on student development.

In the fourth part, specific cases involving the growth mindset of teachers and their interactions with students were presented and discussed. This segment aimed to provide practical examples and foster a deeper understanding of how a growth mindset can be communicated and implemented in educational settings. Each session included time for discussion and questions, allowing participants to engage deeply with the material and relate it to their own teaching experiences.

At the end of the training, all participants were required to complete a posttest, which measured any changes in their growth mindset as a result of the training activities. This comprehensive approach ensured that the training was not only informative but also interactive, providing teachers with both theoretical knowledge and practical skills to enhance their effectiveness in promoting growth mindsets in their students..

Results

The primary goal of this research is to evaluate the impact of Growth Mindset training on the growth mindset of teachers. The growth mindset of the teachers was assessed using a 20-item Growth Mindset scale. Both pretest and posttest scores from this scale were collected for the research data. Before conducting the Paired Sample t-test to analyze these scores, it was necessary to perform an assumption check to validate the use of the t-test method. This involved conducting a normality test to ensure that the data distribution met the assumptions required for this statistical method. The results of this normality test are documented in Table 2, which details whether the dataset followed a normal distribution, thus influencing the appropriateness of the subsequent t-test analysis.

Prior to conducting the analysis, Shapiro-Wilk statistics was computed to examine the assumption of normality for paired samples t-test. The result of Shapiro-Wilk test showed that the assumption of normality was not violated, $W=0.94$,

Table 2. Normality test (Shapiro-Wilk)

		W	p
Pretest	-	Posttest	0.941 0.272

Note. A low p-value suggests a violation of the assumption of normality

Table 3. Descriptives

	N	Mean	Median	SD	SE
Pretest	19	65.632	66	7.182	1.648
Posttest	19	70.053	70	9.089	2.085

Table 4. Paired samples t-test

		Student's t	df	p	Cohen's d
Pretest	Posttest	-3.529	18	0.002	-0.81

$p = 0.272$. selanjutnya uji T Paired Samples T-Test student's. hasil analisis showed pada tabel 4.

The result of the Paired samples t-test reveals that there is a significant difference between teacher Growth mindset before ($M = 65.6$, $SD = 7.18$) and after ($M = 70.1$, $SD = 9.09$) conducting the intervention, $t(19) = -3.53$, $p < .005$. The effect size for this analysis (Cohen's $d = -0.81$) was found to exceed Cohen's (1988) convention for a large effect ($d = .80$). The findings suggest that growth mindset training as an one of training method which has a large significant effect on growth mindset guru.

Discussion

Research has demonstrated that a growth mindset can positively influence students' motivation, resilience, and academic achievement (Dweck, 2006). Additionally, other evidence suggests that the mindset of teachers plays a crucial role in fostering a growth mindset in their students. Teachers who adopt a growth mindset encourage students to view challenges as opportunities for improvement and to embrace failures as learning experiences (Dweck, 2006).

Growth mindset training for teachers is instrumental in helping them understand and implement attitudes and behaviors that facilitate the development of students' potential and achievements. Teachers with a growth mindset significantly impact student motivation. This mindset enables students to recognize that their natural abilities and talents can evolve over time, and that their future success is not predetermined but can be shaped by their efforts.

The findings from this study provide evidence that growth mindset training is an effective strategy for enhancing teachers' growth mindset. This is beneficial as it teaches students to be receptive to feedback and criticism, viewing mistakes as learning opportunities rather than failures. Through a teacher's growth mindset, educators can cultivate a resilient environment where students feel empowered to take risks and persist through challenging tasks. Teachers encourage students to take ownership of their learning, be accountable for their actions, and stay focused on their ultimate goals. By promoting the link between effort and progress, teachers help students believe in their ability to overcome obstacles and achieve their objectives (Yeager & Dweck, 2012).

Teachers with a growth mindset also exemplify the importance of self-reflection and understanding one's strengths and weaknesses. They dedicate time to helping students identify and develop their unique talents and abilities, and to recognize and appreciate the skills of others. Consequently, students learn how to become better communicators, collaborators, and problem-solvers. Moreover, a teacher's growth mindset fosters a sense of belonging in the classroom. They strive to create an environment where everyone feels accepted and respected, providing a safe and supportive space for students to share ideas and be their authentic selves.

One of the significant strengths of this study lies in its focus on the transformative impact of a growth mindset on both educators and students. The research not only underscores the importance of teachers' attitudes in shaping educational outcomes but also highlights how these mindsets can be cultivated through specific training programs. The study's design, which incorporates both pretest and post-test measures, allows for a clear evaluation of changes over time, directly attributable to the intervention. Additionally, the emphasis on practical applications, such as feedback reception and resilience in facing challenges, provides valuable insights that are immediately applicable in educational settings. This research also broadens the understanding of how growth mindsets can influence broader educational practices and student success.

However, the study is not without its limitations. The absence of a control group limits the ability to definitively attribute observed changes to the training alone, as other external factors could also influence the outcomes. The study's focus on a specific demographic group – teachers at an Islamic junior high school – while insightful, may not necessarily generalize to other educational contexts or cultural settings. This specificity can restrict the broader applicability of the findings. Moreover, the reliance on self-reported measures for assessing growth mindset introduces a potential bias, as participants may respond in ways they perceive as socially desirable rather than entirely accurate. Finally, the study's duration and the timing of the posttest assessments may not adequately capture long-term effects and changes in mindset, potentially overlooking the sustained impact or the gradual evolution of attitudes post-training.

To build on the findings of this study, future research could incorporate a longitudinal design with multiple follow-up assessments to track the long-term sustainability of growth mindset changes. Including a control group or using a randomized controlled trial design would strengthen causal inferences. Expanding the participant pool to include teachers from various educational levels and different cultural backgrounds could enhance the generalizability of the results. Additionally, integrating objective measures of teacher performance and student achievement could provide a more comprehensive view of the impact of growth mindset training.

Conclusions

This study makes a compelling case for the implementation of growth mindset training programs for teachers, highlighting its potential to enhance educational practices and student outcomes. The research vividly illustrates that

teachers who develop a growth mindset can profoundly affect their students by fostering an environment that champions resilience, embraces challenges, and celebrates feedback and continuous learning. The evidence suggests that such training not only boosts teachers' confidence and adaptability but also equips them to instill similar qualities in their students, thereby cultivating a classroom atmosphere conducive to greater engagement and achievement. Despite its limitations, the study offers significant insights into the dynamics of growth mindset development within an educational setting and underscores the critical role of teacher attitudes in shaping student success. The research findings advocate for the broader application of growth mindset principles across educational systems to empower both educators and students. It also calls for continued exploration into this area, with adjustments for more robust experimental controls and broader participant demographics to better understand and harness the full potential of growth mindset training. In conclusion, the study conclusively reaffirms the transformative potential of growth mindset training within educational contexts, demonstrating its profound capability to effectuate substantial alterations in the attitudes and behaviors of both educators and students. This, in turn, facilitates the enhancement of educational outcomes and fosters the development of a more adaptable and resilient forthcoming generation.

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Тренінг мислення зростання для вчителя: метод зміни мислення вчителя

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

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Історія питання. Академічна успішність учнів у школах значною мірою формується їхніми психічними установками, особливо коли вони стикаються зі складними ситуаціями, які вимагають значних зусиль і стійкості. Вплив установок, або мислення вчителів, відіграє вирішальну роль в освітньому середовищі, оскільки вони безпосередньо впливають на власне мислення учнів і, відповідно, на їхній підхід до навчання. Зокрема, було показано, що концепція «мислення зростання», тобто віра в те, що здібності та інтелект людини можуть бути розвинені завдяки відданості та наполегливості, змінює те, як люди сприймають свої можливості та реагують на невдачі.

Мета дослідження. У зв'язку з цим було проведено спеціальне дослідження для оцінки ефективності «Тренінгу мислення зростання», орієнтованого на вчителів. Цей тренінг мав на меті виховати мислення зростання серед педагогів, припускаючи, що зміна ставлення вчителів, у свою чергу, позитивно вплине на їхніх учнів.

Матеріали та методи. Щоб оцінити вплив тренінгу, дослідники використовували шкалу мислення зростання, щоб виміряти мислення 19 вчителів-учасників, включаючи 11 жінок і 8 чоловіків, як до, так і після проходження навчальної програми.

Результати. Результати цього дослідження були кількісно надійними, з Т-статистикою -3,529 і рівнем значущості менше 0,005, що вказує на статистично значуще покращення мислення зростання вчителів після навчання. Крім того, аналіз середніх балів з претесту та посттесту ще більше підтвердив тенденцію до зростання, що свідчить про те, що мислення вчителів справді змістилося в бік більш орієнтованої на зростання перспективи.

Висновки. Таким чином, тренінг мислення зростання став потужним інструментом втручання, який не просто змінює сприйняття вчителів, але й потенційно закладає основу для покращення загального освітнього досвіду шляхом виховання культури наполегливості та постійного вдосконалення в школах.

Ключові слова: педагогічна психологія, розвиток вчителя, трансформація мислення, досягнення учнів.

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Dynamics of an AI-Driven Mathematical Model of Some Learning Theories

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Abstract

Objectives. This paper delves into the intersection of mathematical modelling and learning theory, exploring how mathematical frameworks have been instrumental in advancing our understanding of educational processes and pedagogical practices with the aid of Artificial Intelligence (AI).

Material and methods. Advancing learning theories through mathematical modelling offers several significant benefits and opportunities. This is because mathematical models provide a precise and systematic framework for representing complex educational phenomena, allowing researchers to formalize theoretical concepts, relationships, and mechanisms in a clear and rigorous manner.

Results and conclusions. This paper focused on such learning theories as cooperative learning theory, Maslow motivation theory, and social learning theory. By employing mathematical models, researchers have been able to dissect complex educational phenomena, elucidate underlying mechanisms, and predict outcomes with a level of precision that traditional qualitative approaches often struggle to achieve.

Keywords: Learning, Learning theory, Cooperative, Motivation, Social learning theory.

Introduction

Learning is one of the oldest and most unique topics around. It is something that only living things can do and is an integral part of our daily lives. A famous quote that is often misattributed to a conversation between Albert Einstein and a reporter said, “The day you stop learning is the day you start dying.” By this, it means that learning continues until the day we die. We learn from our mistakes, the environment around us, and even the people we interact with every day. We may think learning only involves lessons, schooling, and difficult tasks, but learning is done so passively that no one is untainted by it. And for this purpose, learning theory is somewhat of a grandmother in the understanding of learning. It is the “scientific” study of learning that, though it does not necessarily provide a direct explanation for what we know as learning, we can use it to gain an understanding of how creatures learn. This understanding can be used in various ways, such as training a pet new tricks or enabling a better comprehension of memory recall techniques.

It is difficult to define learning, simple though the concept may be. There have been innumerable attempts to explain what learning is; among some of the best known definitions

are those that identify learning as: a change in behaviour; the acquisition of new knowledge, skills, attitudes, or values; the process of knowing or coming to know; the process of building a mental model of a set of experiences – constructing new interpretations of the world or revising old interpretations; an increase in cognitive complexity; a relatively permanent change in cognitive functioning and the skills required to accomplish a given task (Klang et al., 2021). All of the definitions suggest a somewhat different conception of what is involved in learning, and learning theory covers a broad range of explanatory terrains. From the perspective of the novice educational researcher, learning can be seen as the study of how and why people change. Such a simple view has wide applicability, and research conducted in educational settings is sometimes not overtly about learning, yet it is about learning in the broadest sense of looking to bring about change for the better. A teacher may want to understand why a child who is bright and articulate at home is failing to perform in school, a lecturing clinician may wish to understand the process of acquiring clinical expertise, and a lecturer to understand why students persist in certain misconceptions of the material they are being taught. Such research is all about attempting to understand the processes that lead to change and trying to effect changes that are in the best interests of those involved.

Learning theory is seen as the key vehicle for understanding and improving learning (Davidson & Major, 2014).

A variety of well-known learning theories exist, and they all provide a different framework for understanding and analyzing how people learn. These theories of learning offer conceptual frameworks for comprehending many facets of the process of learning (Obasi, 2023). In order to serve diverse learners in a variety of contexts and influence instructional practices, educators and researchers frequently draw on a variety of theories in their work. Furthermore, new viewpoints and theories in the subject of learning have been developed as a result of developments in cognitive science and technology (Klang et al., 2020). This paper however focused on cooperative theory of learning, Maslow's theory of motivation and social learning theory.

Cooperative Learning Theory

Cooperative learning theory is an educational approach that emphasizes collaborative and interactive learning among students. It is based on the idea that students working together in small groups can achieve better learning outcomes than when working individually. The theory draws on social interdependence and the positive interplay between individual and group goals (Davidson & Major, 2014). Cooperative learning theory has roots in the work of several theorists, and it has evolved over time. One of the key figures associated with the development and popularization of cooperative learning is Dr. David W. Johnson and Dr. Roger T. Johnson, a husband-and-wife team of educational psychologists (Johnson et al., 1993). They have conducted extensive research on cooperative learning and are known for their contributions to the field. Cooperative learning is widely used in classrooms across various educational levels and disciplines. Its success relies on effective implementation, careful task design, and a supportive learning environment that encourages positive interdependence and individual accountability (Klang et al., 2020).

For the field of learning research to progress, the concept of quantifying and assessing knowledge, learning, etc., is crucial. Within education, this is a current problem. According to a quote from Lord Kelvin, educational psychology and pedagogy do not have to be imprecise fields of study (Fadul, 2006). Mathematical models, including differential equations, can be used to describe the dynamics of learning within a cooperative group. These models may consider factors such as the rate of knowledge transfer, individual learning rates, and the impact of collaboration on learning outcomes. The combination of mathematical models with insights from educational psychology provides a more comprehensive understanding of the dynamics within cooperative learning environments. Thus, cooperative learning is seen as a system of linear differential equation which relates a knowledge function to its derivatives. This brings us to a mathematical model for cooperative learning; let us take the example of three students, each of whose knowledge G , K , and R is quantified in terms of the estimated number of connected and unlinked ideas for a given lesson. $G(t)$, $K(t)$, and $R(t)$ are assumed to be functions of time expressed in weeks. Based on previous observations and experiences, the following assumptions are made by our cooperative learning model (Fadul, 2006):

- i. The knowledge of each learner will increase at a rate that is proportional to the knowledge of the other learners;
- ii. The knowledge of each learner may decrease at a rate that is proportional to its own amount of knowledge;
- iii. The rate of change of knowledge for a learner has a constant component that measures the level of amiability (i.e., trust and friendliness) of that learner toward the others.

These assumptions lead to the system of linear differential equation (1) below:

$$\begin{cases} \frac{dG(t)}{dt} = \alpha K + \delta R - \rho G + r(s, h) \\ \frac{dK(t)}{dt} = \beta G + \eta R - \varphi K + s(r, h) \\ \frac{dR(t)}{dt} = \sigma K + \tau G - \nu R + h(r, s) \end{cases} \quad (1)$$

The variables and parameters of the model are described in Table 2 below.

Table 1. Description of variables and parameters of the model

Variable	Description
$G(t)$	Knowledge of first student at a time
$K(t)$	Knowledge of second student at a time
$R(t)$	Knowledge of third student at a time
α	Openness of first student to learning from second student
δ	Openness of first student to learning from third student
ρ	Learning decay rate of first student
β	Openness of second student to learning from first student
η	Openness of second student to learning from third student
φ	Learning decay rate of second student
σ	Openness of third student to learning from second student
τ	Openness of third student to learning from first student
ν	Learning decay rate of third student
r	First student's level of cordiality towards second & third students
s	Second student's level of cordiality towards first & third students
h	Third student's level of cordiality towards first & second students

The constants are non-negative but the numbers have any value: positive values for attitudes of trust for the other, and negative values for antagonism and aversion. In matrix notation, the case may be written as:

$$X' = AX + B$$

$$\begin{pmatrix} G'(t) \\ K'(t) \\ R'(t) \end{pmatrix} = \begin{pmatrix} -\rho & \alpha & \delta \\ \beta & -\varphi & \eta \\ \tau & \sigma & -\nu \end{pmatrix} \begin{pmatrix} G \\ K \\ R \end{pmatrix} + \begin{pmatrix} r \\ s \\ h \end{pmatrix}, A = \begin{pmatrix} -\rho & \alpha & \delta \\ \beta & -\varphi & \eta \\ \tau & \sigma & -\nu \end{pmatrix} \quad (2)$$

We see that the nature of the solutions of the system will depend on the eigenvalues of the matrix A . The determinant, $\det(A)$ and trace, $\text{tr}(A)$ of this matrix play a crucial role in determining the stability of the solutions. If $\det(A) > 0$ and $\text{tr}(A) < 0$, the system is stable. These criteria are derived from the fact that the signs of the eigenvalues influence the stability of the system (Obasi & Mbah, 2019; Obasi, 2023). Posi-

tive real parts of eigenvalues are associated with instability, while negative real parts suggest stability. The determinant and trace help in identifying these signs and making predictions about the system's behaviour. On the roots of the characteristic equation:

$$\lambda^3 + (v + \phi + \rho)\lambda^2 + ((\rho + v)\phi - \sigma\eta + v\rho - \tau\delta - \beta\alpha)\lambda + (\rho v - \delta\tau)\phi - \eta\rho\sigma - \alpha\eta\tau - \alpha\beta v - \beta\delta\sigma = 0 \quad (3)$$

with the determinant and trace of matrix A obtained as:

$$\begin{cases} \det(A) = \sigma(\beta\delta + \eta\rho) + (\alpha\beta - \rho\phi)v + \tau(\alpha\eta + \delta\phi) \\ \text{tr}(A) = -(v + \phi + \rho) \end{cases} \quad (4)$$

It can easily be seen from (4) that $\text{tr}(A)$, but if $\alpha\beta - \rho\phi > 0$ then $\det(A) > 0$, which implies stability. That is, if both learners mildly like each other ($r > 0$, $s > 0$ and $h > 0$) and if the product of their knowledge decay indices is less than the product of their receptivity to learning from each other, there will be joint increased learning. However, if $\alpha\beta - \rho\phi < 0$, and ($r < 0$, $s < 0$ and $h < 0$) there will be retrogression. That is, first student and second student do not like each other and if the product of their knowledge decay indices is greater than the product of the indices of their receptivity to each other's learning, it will lead to retrogression. Their unpracticed or unutilized knowledge will decay.

In the context of cooperative learning, stability often refers to the ability of the system to reach and maintain a desirable state, such as a state where all individuals in the group have acquired and retained knowledge or skills. Consider a simple cooperative learning scenario where individuals positively influence each other's learning, and the matrix A has eigenvalues with negative real parts. In this case, the cooperative learning system is stable, and the group is likely to converge to a state where all individuals have acquired the desired knowledge or skills. Note that stability suggests that the learning trajectories of individuals within the group are predictable and do not exhibit erratic behaviour. Predictability is desirable in educational settings to ensure a steady and effective learning process (Fadul, 2006). Cooperative learning often involves individual accountability and positive interdependence, where the success of one individual benefits the entire group. Systems that promote positive interdependence and individual accountability are more likely to be stable. Stability implies a balance in the interactions between individuals in the cooperative learning group. If the interactions are too competitive or too cooperative, it may lead to instability. It should be noted that stable systems tend to converge to an equilibrium state where learning is balanced and individuals have acquired the desired knowledge or skills. To further understanding system dynamics, exact model solution is determined. Thus, the system of equations (1) are first-order linear ODEs, which can be solved via the matrix method. We have that

$$\begin{cases} X = e^{At} X(0), \quad X(0) = \begin{pmatrix} G_0 \\ K_0 \\ R_0 \end{pmatrix} \\ \frac{dX(t)}{dt} = AX(t) = \begin{pmatrix} -\rho & \alpha & \delta \\ \beta & -\phi & \eta \\ \tau & \sigma & -v \end{pmatrix} \begin{pmatrix} G(t) \\ K(t) \\ R(t) \end{pmatrix}, \quad X(t) = e^{At} \begin{pmatrix} G_0 \\ K_0 \\ R_0 \end{pmatrix}, \text{ but} \\ e^{At} = 1 + At + \frac{A^2}{2!}t^2 + \frac{A^3}{3!}t^3 + \dots \end{cases}$$

$$\therefore e^{At} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} + \begin{pmatrix} -\rho & \alpha & \delta \\ \beta & -\phi & \eta \\ \tau & \sigma & -v \end{pmatrix} t + \frac{1}{2!} \begin{pmatrix} -\rho & \alpha & \delta \\ \beta & -\phi & \eta \\ \tau & \sigma & -v \end{pmatrix}^2 t^2 + \frac{1}{3!} \begin{pmatrix} -\rho & \alpha & \delta \\ \beta & -\phi & \eta \\ \tau & \sigma & -v \end{pmatrix}^3 t^3 + \dots$$

$$= \begin{pmatrix} (1-\rho)t + \frac{1}{2}(a\beta + \delta\tau + \rho^2)t^2 & a\tau - \frac{1}{2}(a\rho + a\phi + \delta\alpha)t^2 & \delta t + \frac{1}{2}(a\eta - \delta\rho + \delta v)t^2 \\ \beta t + \frac{1}{2}(\eta\tau - \beta\rho - \beta\phi)t^2 & (1-\phi)t + \frac{1}{2}(a\beta + \eta\sigma + \phi^2)t^2 & \eta t + \frac{1}{2}(\beta\delta - \eta v - \eta\phi)t^2 \\ \tau t + \frac{1}{2}(\beta\sigma - \rho\tau - \tau v)t^2 & \sigma t + \frac{1}{2}(a\tau - \sigma v - \sigma\phi)t^2 & (1-v)t + \frac{1}{2}(\delta\eta + \eta\sigma + v^2)t^2 \end{pmatrix}$$

$$X = \begin{pmatrix} (1-\rho)t + \frac{1}{2}(a\beta + \delta\tau + \rho^2)t^2 & a\tau - \frac{1}{2}(a\rho + a\phi + \delta\alpha)t^2 & \delta t + \frac{1}{2}(a\eta - \delta\rho + \delta v)t^2 \\ \beta t + \frac{1}{2}(\eta\tau - \beta\rho - \beta\phi)t^2 & (1-\phi)t + \frac{1}{2}(a\beta + \eta\sigma + \phi^2)t^2 & \eta t + \frac{1}{2}(\beta\delta - \eta v - \eta\phi)t^2 \\ \tau t + \frac{1}{2}(\beta\sigma - \rho\tau - \tau v)t^2 & \sigma t + \frac{1}{2}(a\tau - \sigma v - \sigma\phi)t^2 & (1-v)t + \frac{1}{2}(\delta\eta + \eta\sigma + v^2)t^2 \end{pmatrix} \begin{pmatrix} G_0 \\ K_0 \\ R_0 \end{pmatrix}$$

$$X(t) = \begin{pmatrix} G(t) \\ K(t) \\ R(t) \end{pmatrix} = \begin{pmatrix} G_0(1-\rho)t + \frac{1}{2}G_0(a\beta + \delta\tau + \rho^2)t^2 + K_0a\tau - \frac{1}{2}K_0(a\rho + a\phi + \delta\alpha)t^2 + R_0\delta t + \frac{1}{2}R_0(a\eta - \delta\rho + \delta v)t^2 \\ G_0\beta t + \frac{1}{2}G_0(\eta\tau - \beta\rho - \beta\phi)t^2 + K_0(1-\phi)t + \frac{1}{2}K_0(a\beta + \eta\sigma + \phi^2)t^2 + R_0\eta t + \frac{1}{2}R_0(\beta\delta - \eta v - \eta\phi)t^2 \\ G_0\tau t + \frac{1}{2}G_0(\beta\sigma - \rho\tau - \tau v)t^2 + K_0\sigma t + \frac{1}{2}K_0(a\tau - \sigma v - \sigma\phi)t^2 + R_0(1-v)t + \frac{1}{2}R_0(\delta\eta + \eta\sigma + v^2)t^2 \end{pmatrix}$$

Therefore, the solution of the system of equations (1) is obtained as:

$$\begin{cases} G(t) = G_0(1-\rho)t + \frac{1}{2}G_0(a\beta + \delta\tau + \rho^2)t^2 + K_0a\tau - \frac{1}{2}K_0(a\rho + a\phi + \delta\alpha)t^2 + R_0\delta t + \frac{1}{2}R_0(a\eta - \delta\rho + \delta v)t^2 + O(t^3) \\ K(t) = G_0\beta t + \frac{1}{2}G_0(\eta\tau - \beta\rho - \beta\phi)t^2 + K_0(1-\phi)t + \frac{1}{2}K_0(a\beta + \eta\sigma + \phi^2)t^2 + R_0\eta t + \frac{1}{2}R_0(\beta\delta - \eta v - \eta\phi)t^2 + O(t^3) \\ R(t) = G_0\tau t + \frac{1}{2}G_0(\beta\sigma - \rho\tau - \tau v)t^2 + K_0\sigma t + \frac{1}{2}K_0(a\tau - \sigma v - \sigma\phi)t^2 + R_0(1-v)t + \frac{1}{2}R_0(\delta\eta + \eta\sigma + v^2)t^2 + O(t^3) \end{cases}$$

as $t \rightarrow \infty, G(t) \rightarrow \infty, K(t) \rightarrow \infty, R(t) \rightarrow \infty$

The exact solutions above show the idea that knowledge of students in cooperative learning could theoretically approach infinity as time tends to infinity. This indicates that there is a situation or condition described as "unbounded in time" which leads to a consequence of "unleashed" increased learning for the learners. This means a growth or enhancement in the process of acquiring knowledge or skills. Thus, the result of a situation being "unbounded in time" is that it allows for a significant and unrestrained increase in learning for the individuals involved. This might imply that without time constraints or limitations, learners are able to explore, absorb, and acquire knowledge in a more effective or accelerated manner. The use of "unleashed" suggests a kind of freedom or release that enables a fuller and more extensive learning experience.

Therefore, the mathematical formulation provides a theoretical framework for exploring the cooperative theory of learning in a controlled and abstract manner. The study indicates that the mathematical model proposed for the cooperative theory of learning demonstrates a high degree of accuracy in predicting learning outcomes within cooperative learning environments. The model has successfully captured the complex interactions and dynamics involved in collaborative learning settings. The mathematical formulations have allowed for a deeper understanding of the dynamics between

individual and group learning. The study highlights how individual contributions impact the overall group learning process and vice versa, providing a nuanced perspective on the interplay between individual and collective knowledge acquisition. The mathematical model and findings from this paper have direct implications for educational practices. Educators can use the insights to design and implement co-operative learning activities that are not only pedagogically sound but also backed by quantitative evidence supporting their effectiveness.

Abraham Maslow's Motivation Theory

Abraham Maslow's motivation theory, often represented as Maslow's Hierarchy of Needs, outlines a hierarchical model of human needs, with each level building upon the previous one. Abraham Maslow proposed a hierarchical model of human needs, arranged in a pyramid. According to Maslow (1943), individuals are motivated to fulfill basic physiological needs (such as food and shelter) before progressing to higher-level needs like safety, belongingness, esteem, and self-actualization. This theory, introduced by Maslow in the mid-20th century, is not specifically focused on learning but provides a framework for understanding human motivation, including aspects related to education and learning (Maslow, 1968). Maslow's Hierarchy of Needs has since become a foundational concept in psychology and education, influencing discussions on motivation, human development, and the design of effective learning environments (Young, 1936). While Maslow did not specifically focus on education in his original works, educators and psychologists have applied and adapted his theory to better understand and address the motivational aspects of the learning process (Tay & Diener, 2011). We can attempt to create a simplified mathematical model inspired by the theory. Let us consider a system of differential equations that represent the dynamics of the hierarchy of needs:

$$\begin{cases} \frac{dP(t)}{dt} = -\alpha P(t) \\ \frac{dS(t)}{dt} = \beta P(t) - \delta S(t) \\ \frac{dB(t)}{dt} = \phi S(t) - \rho B(t) \\ \frac{dE(t)}{dt} = \varphi B(t) - \eta E(t) \\ \frac{dA(t)}{dt} = \sigma E(t) \end{cases} \quad (5)$$

The first equation represents the rate of change of physiological needs (P), indicating a natural decrease over time without external inputs. The second equation represents the dynamics of safety needs. Safety needs (S) increase when physiological needs (P) are satisfied but decrease naturally over time without further inputs. The third equation describes Belongingness and love needs (B) which increase when safety needs (S) are satisfied but decrease naturally over time without further inputs. In the fourth equation, esteem needs (E) increase when belongingness and love needs (B) are satisfied but decrease naturally over time without further inputs. The fifth equation represents the dynamics of Self-actualization (A) which increases when esteem needs (E) are satisfied. In these equations: represent the levels of physiological needs,

safety needs, belongingness and love needs, esteem needs, and self-actualization, respectively. The values of $\alpha, \beta, \delta, \phi, \rho, \varphi, \eta, \sigma$ are positive constants representing the impact of one need level on the rate of change of the next. These equations attempt to capture the idea that the satisfaction of one level of need contributes positively to the next level while recognizing that needs naturally decrease over time if not continuously satisfied. In matrix notation, the case may be written as:

$$X'(t) = AX(t)$$

$$\begin{pmatrix} P'(t) \\ S'(t) \\ B'(t) \\ E'(t) \\ A'(t) \end{pmatrix} = \begin{pmatrix} -\alpha & 0 & 0 & 0 & 0 \\ \beta & -\delta & 0 & 0 & 0 \\ 0 & \phi & -\rho & 0 & 0 \\ 0 & 0 & \varphi & -\eta & 0 \\ 0 & 0 & 0 & \sigma & 0 \end{pmatrix} \begin{pmatrix} P(t) \\ S(t) \\ B(t) \\ E(t) \\ A(t) \end{pmatrix}, A = \begin{pmatrix} -\alpha & 0 & 0 & 0 & 0 \\ \beta & -\delta & 0 & 0 & 0 \\ 0 & \phi & -\rho & 0 & 0 \\ 0 & 0 & \varphi & -\eta & 0 \\ 0 & 0 & 0 & \sigma & 0 \end{pmatrix} \quad (6)$$

We see that the nature of the solutions of the system will depend on the eigenvalues of the matrix. On the roots of the characteristic equation:

$$\lambda^5 + (\alpha + \delta + \rho + \eta)\lambda^4 + (\alpha\delta + \alpha\eta + \alpha\rho + \delta\eta + \delta\rho + \eta\rho)\lambda^3 + (\alpha\delta\eta + \alpha\delta\rho + \alpha\eta\rho + \delta\eta\rho)\lambda^2 + \eta\rho\delta\alpha\lambda = 0 \quad (7)$$

with eigenvalues obtained as:

$$\lambda_{i,i=1,2,3,4,5} = \begin{pmatrix} 0 \\ -\rho \\ -\eta \\ -\delta \\ -\alpha \end{pmatrix} \quad (8)$$

It can easily be seen from (8) that all the eigenvalues are negative except one which is zero. The zero eigenvalue can lead to different stability scenarios depending on the nature of the accompanying eigenvalues. If all other eigenvalues have negative real parts, the equilibrium is a stable center (Obasi, 2023). The negative eigenvalues indicate that small perturbations from the equilibrium will decay over time, and the system will return to the balanced state. In the context of the hierarchy of needs, negative eigenvalues would imply that, when the physiological, safety, and love and belonging needs are at an equilibrium point, any deviations from this point are dampened, and the individual tends to return to a balanced state in terms of these needs. This suggests a stable and adaptive psychological state where the person's needs are generally met and maintained over time. In practical terms, this means that individuals are inclined to return to a balanced state where their physiological, safety, and social needs are met.

Stability in the system implies that when an individual's needs are satisfied at a certain level, they are more likely to maintain a state of well-being. The negative eigenvalues reflect a tendency for individuals to maintain a balanced and satisfied state in terms of their needs, fostering psychological well-being. Negative eigenvalues suggest that the system is adaptive and resilient to perturbations. In the face of external or internal challenges, individuals tend to return to a stable

state. This aligns with Maslow's idea that individuals have an inherent drive for self-actualization and growth, and negative eigenvalues indicate a capacity to adapt and recover from disruptions. The hierarchy of needs is characterized by the transition from lower-level needs to higher-level needs as lower-level needs are satisfied. Individuals, having satisfied lower-level needs, are more likely to progress to addressing higher-level needs, such as esteem and self-actualization, in a stable manner. To further understand the system dynamics, exact model solution is determined. Thus, the system of equations (5) are first-order linear ODEs, which can be solved via the integrating factor method. Therefore, the exact solutions of the system of equations (5) is obtained as:

$$\begin{aligned}
 P(t) &= P_0 e^{-\alpha t}, \text{ as } t \rightarrow \infty, P(t) \rightarrow 0 \\
 S(t) &= \frac{P_0 \beta}{\delta - \alpha} e^{(\delta - \alpha)t} + \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) e^{-\beta t}, \text{ as } t \rightarrow \infty, S(t) \rightarrow 0, \delta < \alpha \\
 B(t) &= B_0 e^{-\beta t} \left[\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} e^{(\delta - \alpha + \beta)t} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) e^{(\delta - \alpha)t} \right] + \left[B_0 - \phi \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) \right] e^{-\beta t}, \text{ as } t \rightarrow \infty, B(t) \rightarrow 0 \\
 E(t) &= \left[\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} e^{(\delta - \alpha + \eta)t} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) e^{(\delta - \alpha)t} + \frac{B_0}{\beta - \eta} e^{(\beta - \eta)t} - \frac{\phi}{2\beta - \eta} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) e^{(\delta - \alpha)t} \right] \\
 &+ \left[E_0 - \phi \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) + \frac{B_0}{\beta - \eta} - \frac{\phi}{2\beta - \eta} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) \right) \right] e^{(\delta - \alpha)t} \\
 \text{as } t \rightarrow \infty, E(t) &\rightarrow E', \text{ provided } \delta - \alpha + \eta < 0, \delta - \eta < 0, \beta - \eta > 0, 2\beta - \eta > 0, \\
 \text{where} \\
 E' &= E_0 - \phi \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) + \frac{B_0}{\beta - \eta} - \frac{\phi}{2\beta - \eta} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) \right) \\
 A(t) &= \alpha \phi \left[\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} e^{(\delta - \alpha + \eta)t} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) e^{(\delta - \alpha)t} + \frac{B_0}{\beta - \eta} e^{(\beta - \eta)t} + \frac{\phi}{(2\beta - \eta)} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) e^{(\delta - \alpha)t} \right] \\
 &+ \left[E_0 - \phi \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) + \frac{B_0}{\beta - \eta} - \frac{\phi}{2\beta - \eta} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) \right) \right] e^{(\delta - \alpha)t} \\
 &+ A_0 - \alpha \phi \left[\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) + \frac{B_0}{\beta - \eta} - \frac{\phi}{2\beta - \eta} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) \right] \\
 \text{as } t \rightarrow \infty, A(t) &\rightarrow A', \text{ provided } \delta - \alpha + \eta < 0, \delta - \eta < 0, \beta - \eta > 0, 2\beta - \eta > 0, \\
 \text{where} \\
 A' &= A_0 - \alpha \phi \left[\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)(\delta - \alpha + \eta)} + \frac{1}{(\beta - \delta)(\delta - \eta)} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) + \frac{B_0}{\beta - \eta} - \frac{\phi}{2\beta - \eta} \left(\frac{P_0 \beta}{(\delta - \alpha)(\delta - \alpha + \beta)} + \frac{1}{\beta - \delta} \left(S_0 + \frac{P_0 \beta}{\delta - \alpha} \right) \right) \right]
 \end{aligned}$$

From the exact solutions, the tendency of physiological, safety, belongingness and love, esteem, and self-actualization needs to approach zero or equilibrium values indicates a long-term stability in the system. Individuals in the model reach a balanced state where their various needs, spanning from basic survival to higher-level self-fulfillment, are either completely satisfied or in a state of sustained equilibrium. The result suggests that, over time, individuals progress through Maslow's hierarchy of needs and eventually reach a state where the pursuit of these needs becomes less dominant. Basic physiological and safety needs tend to zero, indicating that individuals achieve a stable state of physical well-being and security. Meanwhile, higher-level needs like belongingness, esteem, and self-actualization tend to equilibrium values, suggesting a sustained and balanced pursuit of social connection, recognition, and personal growth.

The findings imply that individuals in the model adapt to their environments and find satisfaction in the fulfillment of their diverse needs. As basic needs are met, the focus shifts to higher-level needs, leading to a dynamic and evolving psychological state. The tendency of self-actualization needs to approach equilibrium values indicates that individuals, even in a state of equilibrium, continue to experience per-

sonal growth and pursue self-fulfillment. This aligns with Maslow's concept of self-actualization as an ongoing process of realizing one's potential. This goes to show that individuals have a natural inclination to maintain a stable and satisfied state, adapting to changing circumstances while progressing through the hierarchy of needs. This stability aligns with the notion that individuals strive for fulfillment and self-actualization in a resilient and balanced manner. The result suggests a long-term stability and adaptation in the modeled hierarchy of needs. Individuals reach a balanced state where basic needs are satisfied, and higher-level needs are pursued in a sustainable and evolving manner. The exact solutions highlight the dynamic and continuous nature of human motivation and well-being as individuals progress through the hierarchy over an extended period.

Social Learning Theory

Social learning theory (SLT), developed by psychologist Albert Bandura (Bandura, 1977), is a comprehensive theory that emphasizes the importance of social interactions in learning. It proposes that individuals learn not only through direct experiences but also by observing others and modeling their behaviours, attitudes, and emotional reactions. Bandura's work expanded traditional behaviourist theories by integrating cognitive and social aspects into the learning process. The key concepts of social learning theory include: observational learning, modeling, reinforcement, attention, retention, reproduction, motivation, and self-efficacy (Bandura, 1986). Observational learning also known as modeling or vicarious learning occurs when individuals observe the actions and outcomes of others and incorporate this information into their own behaviours. Bandura's famous Bobo doll experiment demonstrated how children learned aggressive behaviours by observing adults. Modeling involves imitating the behaviours of role models or significant others. Individuals are more likely to emulate behaviours they perceive as rewarding or socially acceptable. For example, children may imitate the behaviours of parents, teachers, or peers. While traditional behaviourist theories emphasize external reinforcement, SLT suggests that reinforcement can be vicarious (Bandura & Walters, 1977). Individuals are motivated to imitate behaviours that result in positive outcomes for others. Conversely, observing negative consequences for certain behaviours may inhibit imitation. Bandura proposed a four-step process involved in observational learning. Individuals must pay attention to the model's behaviour and its consequences. They must remember the observed behaviour. Individuals must have the ability to reproduce the observed behaviour. Finally, individuals are more likely to imitate behaviours if they are motivated to do so, either through intrinsic or extrinsic factors. Central to social learning theory is the concept of self-efficacy, which refers to an individual's belief in their own ability to succeed in specific situations or accomplish tasks (Bandura, 2001). Bandura argued that self-efficacy influences motivation, behaviour, and resilience in the face of challenges.

Representing social learning theory using mathematics offers several advantages. Mathematical models provide a systematic framework for quantitatively analyzing the dynamics of social learning. By expressing SLT concepts in mathemati-

cal terms, researchers can conduct rigorous analyses, perform simulations, and make predictions about learning outcomes. Mathematics enables clear and precise formulation of SLT concepts, making them easier to understand and communicate. Mathematical models can formalize complex relationships between variables, parameters, and processes involved in social learning. Mathematical modeling allows researchers to dissect and understand the underlying mechanisms driving social learning. By representing SLT in mathematical terms, researchers can identify key factors influencing learning outcomes and explore how they interact. Well-constructed mathematical models of SLT can yield predictive insights into learning behaviours and outcomes. Researchers can use simulations to explore hypothetical scenarios and assess the potential impact of interventions or changes in social contexts. In the words of Fadul (2006), mathematics serves as a common language across disciplines, facilitating interdisciplinary integration of SLT with fields such as psychology, sociology, education, and computer science. Mathematical modeling encourages collaboration and exchange of ideas among researchers from diverse backgrounds. Mathematical models of SLT can inform the design of educational interventions and instructional strategies. By understanding the underlying mechanisms of social learning, educators can develop more effective approaches to teaching and fostering collaborative learning environments.

By leveraging mathematical tools and techniques, learning theorists can develop precise models, formulate hypotheses, conduct empirical studies, and derive insights into the mechanisms underlying learning processes and behaviour. Mathematics provides a rigorous framework for studying and understanding the complexities of learning theory, facilitating advancements in educational research and practice (Fadul, 2006). Therefore, representing social learning theory using mathematics enhances our understanding of the complex interplay between social interactions, cognitive processes, and learning outcomes. Mathematical modeling provides a powerful tool for exploring, analyzing, and advancing our knowledge of social learning phenomena. To develop a system of differential equations describing social learning theory, we need to consider the key components of this theory, which emphasize learning through observation, modeling, and social interaction. The model variables and parameters are defined in Table 2.

Table 2. Model variable and parameter descriptions

Variables	Descriptions
$L(t)$	Level of learning or knowledge at time
$I(t)$	Intensity of exposure to social interactions or observational learning at time.
Parameters	
α	Rate at which learning occurs through observation.
β	Rate at which learning occurs through direct experience or instruction.
γ	Rate at which forgetting occurs.
σ	Influence of reinforcement or feedback.

Based on these variables and parameters, we can formulate a system of differential equations describing the social learning theory as developed Albert Bandura:

$$\frac{L(t)}{dt} = \alpha I(t) - \beta L(t) - \gamma L(t) \quad (9)$$

This equation describes how the level of learning ($L(t)$) changes over time. Learning increases based on the intensity of exposure to social interactions ($I(t)$) with a rate proportional to α . Learning also decreases over time due to forgetting ($\gamma L(t)$) and through direct experience or instruction ($\beta L(t)$). Additionally, we can introduce a differential equation to model the intensity of exposure to social interactions ($I(t)$):

$$\frac{I(t)}{dt} = \delta (L(t) - I(t)) \quad (10)$$

This equation describes how the intensity of exposure to social interactions changes over time. It depends on the difference between the level of learning ($L(t)$) and the current intensity of exposure to social interactions ($I(t)$), with a rate proportional to σ . Thus, putting the two equations together we have

$$\begin{cases} \frac{L(t)}{dt} = \alpha I(t) - \beta L(t) - \gamma L(t) \\ \frac{I(t)}{dt} = \delta (L(t) - I(t)) \end{cases} \quad (11)$$

This system of differential equations captures the essence of social learning theory by modeling how learning evolves over time through observation, direct experience, forgetting, and feedback from social interactions. Adjustments and refinements can be made to this model to account for specific contexts and factors influencing social learning. In matrix notation, the case may be written as:

$$\begin{aligned} X'(t) &= AX(t) \\ \begin{pmatrix} L'(t) \\ I'(t) \end{pmatrix} &= \begin{pmatrix} -(\beta + \gamma) & \alpha \\ \delta & -\delta \end{pmatrix} \begin{pmatrix} L(t) \\ I(t) \end{pmatrix} \end{aligned} \quad (12)$$

We see that the nature of the solutions of the system will depend on the eigenvalues of the matrix. The determinant, and trace, of this matrix play a crucial role in determining the stability of the solutions. If and , the system is stable. These criteria are derived from the fact that the signs of the eigenvalues influence the stability of the system (Obasi & Mbah, 2019; Obasi, 2023). Positive real parts of eigenvalues are associated with instability, while negative real parts suggest stability. The determinant and trace help in identifying these signs and making predictions about the system's behaviour. On the roots of the characteristic equation:

$$\lambda^2 + (\delta + \beta + \gamma)\lambda - \delta\alpha + \delta\beta + \delta\gamma = 0 \quad (13)$$

with the determinant and trace of matrix A obtained as:

$$\begin{cases} \det(A) = -\delta\alpha + \delta\beta + \delta\gamma \\ \text{tr}(A) = -(\delta + \beta + \gamma) \end{cases} \quad (14)$$

It can easily be seen from (14) that, $\text{tr}(A) < 0$, but if $\beta + \gamma > \alpha$ then $\det(A) > 0$, which implies stability. That is, if the sum of rate at which learning occurs through direct experience or instruction and the rate at which forgetting occurs is greater than the rate at which learning occurs through observation, there will be increased learning. In the context of social learning theory, stability in the system of differential equations implies that the behaviours or patterns modeled by the equations tend to settle down or remain consistent over

time. When the system is stable, it suggests that the dynamics of learning and behaviour tend to reach an equilibrium or a steady state. In other words, the behaviours modeled by the equations don't wildly fluctuate or diverge from each other over time. Instead, they converge towards certain patterns or norms, reflecting the stability of the social learning process within the theoretical framework being studied. This finding suggests that the effectiveness of learning can be enhanced when the combined rate of learning from direct experience or instruction, along with the rate of forgetting, surpasses the rate of learning through observation. This underscores the importance of active learning approaches, such as hands-on practice, interactive instruction, and spaced repetition, in promoting deep understanding and long-term retention of knowledge and skills. By balancing direct experience with effective instructional techniques and reinforcement strategies, educators and learners can optimize the learning process and enhance educational outcomes.

The stability of social learning theory in the context of learning has several important implications. Stable social learning processes imply that individuals are likely to consistently adopt and exhibit behaviours that are learned from observing others in their social environment. This consistency can lead to the establishment and maintenance of social norms and cultural practices within a group or society. When social learning processes are stable, it becomes easier to predict how individuals will respond to different social cues or stimuli. This predictability can be valuable for educators, policymakers, and social scientists who seek to understand and influence behaviour within various social contexts. It facilitates the transmission of knowledge, skills, and cultural traditions across generations. When individuals reliably learn from their social environment, valuable information and practices can be passed down from one generation to the next, contributing to the continuity and evolution of society. More so, it can contribute to social cohesion by promoting shared values, beliefs, and behaviours within a group or community. When individuals consistently learn from and imitate each other, it fosters a sense of belonging and solidarity, which can strengthen social bonds and cooperation. While stability implies consistency, it does not necessarily mean rigidity. Social learning processes can also be adaptive, allowing individuals and societies to respond to changing circumstances and environments. Stable social learning frameworks provide a foundation upon which new behaviours and innovations can be integrated and disseminated. A stable social learning system can enhance the resilience of individuals and communities by providing a reliable mechanism for acquiring knowledge and coping strategies in the face of challenges or adversity. Consistent learning from others can help individuals navigate uncertain or unfamiliar situations more effectively. Thus, the stability of social learning theory in learning underscores its significance as a fundamental mechanism through which individuals acquire knowledge, skills, and social behaviours within their cultural and social contexts. To further understand the system dynamics, exact model solution is determined. The system of equations (11) are first-order linear ODEs, which can be solved via the matrix method. We have that

$$\begin{aligned}
 X &= e^{At} X(0), \quad X(0) = \begin{pmatrix} L_0 \\ I_0 \end{pmatrix} \\
 \frac{dX(t)}{dt} &= AX(t) = \begin{pmatrix} -(\beta+\gamma) & \alpha \\ \delta & -\delta \end{pmatrix} \begin{pmatrix} L(t) \\ I(t) \end{pmatrix}, \quad X(t) = e^{At} \begin{pmatrix} L_0 \\ I_0 \end{pmatrix}, \text{ but} \\
 e^{At} &= 1 + At + \frac{A^2}{2!}t^2 + \frac{A^3}{3!}t^3 + \dots \\
 \therefore e^{At} &= \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} + \begin{pmatrix} -(\beta+\gamma) & \alpha \\ \delta & -\delta \end{pmatrix}t + \frac{1}{2!} \begin{pmatrix} -(\beta+\gamma) & \alpha \\ \delta & -\delta \end{pmatrix}^2 t^2 + \frac{1}{3!} \begin{pmatrix} -(\beta+\gamma) & \alpha \\ \delta & -\delta \end{pmatrix}^3 t^3 + \dots \\
 &= \begin{pmatrix} 1 - (\beta+\gamma)t + \frac{1}{2}((\beta+\gamma)^2 + \delta\alpha)t^2 & at - \frac{1}{2}(\beta+\gamma-\delta)at^2 \\ \delta t - \frac{1}{2}(\beta+\gamma-\delta)\delta t^2 & 1 - \delta t + \frac{1}{2}(\alpha+\delta)\delta t^2 \end{pmatrix} \\
 X &= \begin{pmatrix} 1 - (\beta+\gamma)t + \frac{1}{2}((\beta+\gamma)^2 + \delta\alpha)t^2 & at - \frac{1}{2}(\beta+\gamma-\delta)at^2 \\ \delta t - \frac{1}{2}(\beta+\gamma-\delta)\delta t^2 & 1 - \delta t + \frac{1}{2}(\alpha+\delta)\delta t^2 \end{pmatrix} \begin{pmatrix} L_0 \\ I_0 \end{pmatrix} \\
 X(t) \equiv (L(t), I(t)) &= \begin{pmatrix} L_0 - (\beta+\gamma)L_0t + \frac{1}{2}L_0((\beta+\gamma)^2 + \delta\alpha)t^2 + I_0at - \frac{1}{2}I_0(\beta+\gamma-\delta)at^2 \\ L_0\delta t - \frac{1}{2}L_0(\beta+\gamma-\delta)\delta t^2 + I_0(1-\delta t) + \frac{1}{2}I_0(\alpha+\delta)\delta t^2 \end{pmatrix}
 \end{aligned}$$

Therefore, the solution of the system of equations (11) is obtained as:

$$\begin{cases} L(t) = L_0 - (\beta+\gamma)L_0t + \frac{1}{2}L_0((\beta+\gamma)^2 + \delta\alpha)t^2 + I_0at - \frac{1}{2}I_0(\beta+\gamma-\delta)at^2 + O(t^3) \\ I(t) = L_0\delta t - \frac{1}{2}L_0(\beta+\gamma-\delta)\delta t^2 + I_0(1-\delta t) + \frac{1}{2}I_0(\alpha+\delta)\delta t^2 + O(t^3) \end{cases} \quad (15)$$

as $t \rightarrow \infty$, $L(t) \rightarrow \infty$, $I(t) \rightarrow \infty$

The exact solutions (15) above show the idea that level of learning or knowledge and the intensity of exposure to social interactions or observational learning could theoretically approach infinity as time tends to infinity. This suggests that, theoretically, there is no upper limit to the level of learning or knowledge that individuals can attain, nor to the intensity of exposure to social interactions or observational learning, given an infinite amount of time. Level of learning or knowledge refers to the depth and breadth of understanding that individuals can achieve in various domains, such as academic subjects, skills, or personal development. The finding suggests that as individuals engage in learning activities over an extended period, their level of knowledge can continue to grow indefinitely. This implies that there is always more to learn, discover, and understand, and that the process of learning is potentially limitless. It goes to show that social interactions and observational learning play crucial roles in the learning process. Through interactions with others, individuals can exchange ideas, perspectives, and information, which can enrich their understanding and stimulate further learning. Observational learning, where individuals learn by observing and imitating others, also contributes significantly to the acquisition of new skills and behaviours. The finding suggests that as individuals engage in more social interactions and observational learning experiences over time, the potential for learning increases without bounds.

Therefore, given an infinite amount of time, there is no limit to how much individuals can learn or how intensive-

ly they can engage in social interactions or observational learning. In other words, as time goes on indefinitely, the potential for learning and exposure to learning opportunities continues to grow without constraint. However, it is essential to note that while this finding provides an intriguing theoretical perspective on the potential for lifelong learning and continuous personal growth, it is practically impossible for individuals to have infinite time or resources for learning. In reality, people have finite lifespans, limited resources, and various constraints that affect their learning opportunities. Nonetheless, the idea that learning and exposure to learning experiences can continue to expand without limit underscores the importance of fostering a lifelong learning mindset and seeking out opportunities for growth and development throughout one's life.

Concluding Remarks

This paper delves into the intersection of mathematical modeling and learning theory, exploring how mathematical frameworks have been instrumental in advancing our understanding of educational processes and pedagogical practices. Advancing learning theories through mathematical modeling offers several significant benefits and opportunities. This is because mathematical models provide a precise and systematic framework for representing complex educational phenomena, allowing researchers to formalize theoretical concepts, relationships, and mechanisms in a clear and rigorous manner. This paper focused on such learning theories as cooperative learning theory, Maslow motivation theory, and social learning theory. By employing mathematical models, researchers have been able to dissect complex educational phenomena, elucidate underlying mechanisms, and predict outcomes with a level of precision that traditional qualitative approaches often struggle to achieve.

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Динаміка математичної моделі деяких теорій навчання на основі штучного інтелекту

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 5 с., 4 табл., 36 джерел.

Мета дослідження. У цій статті розглянутий взаємозв'язок математичного моделювання та теорії навчання, досліджено, як математичні рамки відіграли важливу роль у просуванні нашого розуміння освітніх процесів і педагогічних практик за допомогою штучного інтелекту (ШІ).

Матеріал і методи. Розвиток теорій навчання за допомогою математичного моделювання пропонує кілька значних переваг і можливостей. Це пов'язано з тим, що математичні моделі забезпечують точну та систематичну основу для пред-

ставлення складних освітніх явищ, дозволяючи дослідникам формалізувати теоретичні концепції, взаємозв'язки та механізми у чіткий та строгий спосіб.

Результати та висновки. Ця стаття була присвячена таким теоріям навчання, як теорія кооперативного навчання, теорія мотивації Маслоу та теорія соціального навчання. Використовуючи математичні моделі, були проаналізовані складні освітні явища, з'ясовані основні механізми та передбачені результати з таким рівнем точності, якого часто важко досягти традиційними якісними підходами.

Ключові слова: навчання, теорія навчання, кооператив, мотивація, теорія соціального навчання.

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