The impact of STEAM education using robotics on the executive function of typical and ADHD students along with developmental exploration

Nikolaos Drakatos[1] & Athanasios Drigas[1]

[1] Institute of Informatics and Telecommunications, NCSR Demokritos, Athens, Greece

Correspondence: Athanasios Drigas, Institute of Informatics and Telecommunications, NCSR Demokritos, Athens, Greece. E-mail: dr@iit.demokritos.gr

Received: August 28, 2023
Accepted: December 14, 2023
DOI: 10.14295/bjs.v3i2.467
URL: https://doi.org/10.14295/bjs.v3i2.467

Abstract

Educational Robotics (ER) is a novel learning approach renowned mostly for its effects on scientific academic disciplines such as science, technology, engineering, arts and mathematics (STEAM). According to recent research, ER can also influence cognitive development by increasing critical reasoning and planning abilities. The purpose of this study was to quantify the potential of ER to empower Executive Functions (EF), including the ability to govern, update, and program information. Executive Function (EF) refers to a complex set of cognitive control processes required for adaptive daily functioning. EFs are more predictive of intellectual progress, health, wealth, and quality of life over the life span than IQ or socioeconomic position. Evidence suggests that EFs can be divided into three core capacities (working memory, inhibition, and shifting), which work together to support higher-order cognitive processing (e.g., planning, problem solving) required to stay on track, resist contrary impulses and distraction, and pursue more-positive (rather than most-immediate) outcomes. Given the importance of EFs, there is a growing interest in enhancing them. The current study sought also to validate the ER's efficacy on EF in children with ADHD.

Keywords: Educational robotics, executive functions, STEAM, ADHD.

O impacto do ensino STEAM com recurso à robótica na função executiva de alunos típicos e com TDAH, juntamente com a exploração do desenvolvimento

Resumo

A robótica educativa (RE) é uma nova abordagem de aprendizagem conhecida sobretudo pelos seus efeitos nas disciplinas académicas científicas, como as ciências, a tecnologia, a engenharia, as artes e a matemática (STEAM). De acordo com investigações recentes, a ER também pode influenciar o desenvolvimento cognitivo, aumentando o raciocínio crítico e as capacidades de planeamento. O objetivo deste estudo foi quantificar o potencial do ER para reforçar as funções executivas (FE), incluindo a capacidade de gerir, atualizar e programar informações. A função executiva (FE) refere-se a um conjunto complexo de processos de controlo cognitivo necessários para o funcionamento diário adaptativo. As FE são mais preditivas do progresso intelectual, da saúde, da riqueza e da qualidade de vida ao longo da vida do que o QI ou a posição socioeconómica. As evidências sugerem que as FE podem ser divididas em três capacidades nucleares (memória de trabalho, inibição e mudança), que trabalham em conjunto para apoiar o processamento cognitivo de ordem superior (por exemplo, planeamento, resolução de problemas) necessário para se manter no caminho certo, resistir a impulsos contrários e distração, e procurar resultados mais positivos (em vez dos mais imediatos). Dada a importância das FE, existe um interesse crescente em melhorá-las. O presente estudo procurou também validar a eficácia do ER nas FE em crianças com PDAH.

Palavras-chave: Robótica educativa, funções executivas, STEAM, PDAH.

1. Introduction

Executive Functions evolve with time and are finished in late adolescence (Garon et al., 2008). School is a vital time for EF growth and is linked to scholastic milestones. EF development includes both quantitative and qualitative changes. According to some research, there is an undifferentiated executive control factor in toddlers, while a two-factor model consisting of inhibition and working memory appears between the ages of 3 and 5 years (Miller et al., 2012). Another two-factor model in which inhibition is distinguished from working memory and shifting (which resembles the cognitive flexibility component of Diamond's model) has been identified in 5- and 6-year-old children, followed by the emergence of a separate three-factor structure later in development (Usai et al., 2014). However, these trajectories are not uniformly confirmed, and findings from a recent comprehensive analysis (Karr et al., 2018) demonstrate that no model consistently converges across samples, but there is evidence for increasing EFs unidimensionality among child/adolescent samples. Disentangling the many ideas on the developmental EFs structure is outside the scope of this study. However the diverse types of tasks and tests utilized in the different studies may have contributed to the great variability of the results (Miller et al., 2012). Both the EF models and the measures employed may influence the methodological choices and findings gained in intervention studies aimed at boosting EF development (Drigas; Karyotaki, 2019).

Educational robotics labs have gradually introduced increasingly demanding robot programming exercises. The children were examined using standardized examinations, and the results revealed that ER-Lab activities increased some superior cognitive skills, such as Executive skills (EFs). Robot programming needs students to cognitively organize a complex sequence of movements before doing the motor act: The child was required to set the target or targets to be reached, then plan the sequential steps required to attain the target, and lastly, at the end of the programming, to act and check his or her behavior. This type of task involves several complicated superior cognitive functions, including as abstraction and logical reasoning, decision-making, sequential thinking, preserving and updating information in memory, and problem-solving, all of which are related to the EFs cognitive domain. The literature agrees that EFs are a group of top-down processes crucial for adaptive and goal-directed behavior (Chaidi et al., 2021). However, several disagreements exist regarding the definition and differentiation of separable EF components during development because we now recognize the internal complexity of each factor as well as the unity and diversity of the various EF components (Karr et al., 2018; Chaidi et al., 2021). Diamond’s (2013) approach is widely used from a developmental standpoint. This model has three major EF factors: Inhibition, working memory, and cognitive flexibility are all closely linked to more complex EFs like thinking, planning, and problem solving. According to Diamond's definitions, inhibition is a complex construct theorized as a set of functions rather than a unitary construct, distinguishing response inhibition at the behavior level from interference control at the memory, thoughts, and attention levels; working memory involves holding visual or verbal information in mind and mentally working with it; and cognitive flexibility is the ability to efficiently change spatial and interpersonal perspectives.

Most past studies that have focused on enhancing EFs during development differ from those that have focused on defining EF structure and methods of assessing the various EF components; nonetheless, certain general concepts applicable for intervention studies have been discovered. Recent research indicates that EFs may be trained, and that in order to achieve meaningful changes, the training must: (1) develop incrementally more difficult activities based on adaptive and intensive paradigms, as demonstrated by studies on home-based software (Thorell et al., 2009), (2) be administered over long training phases, particularly for very young participants, (3) continuously monitor participation levels .. (4) constantly challenge EFs to produce improvements, and (5) provide diverse and heterogeneous training (Diamond; Ling, 2016).

2. Theoretical Reference

Executive Functioning and STEAM are essential for success

Executive function (EF) insufficiency, according to Bellman et al. (2015), is one of the most significant hurdles to performance and persistence for students with disabilities (SWDs) in postsecondary STEM. Researchers discovered that EF impairments typically have an impact on academic, social, vocational, and psychological functioning (Drigas; Karyotaki, 2017). EFs explain the ability to manage goal-oriented and purposeful actions in daily life. Researchers discovered that EFs (i.e., strategy generation and planning) develop constantly between the ages of 17 and 22 through early adulthood (Romine; Reynolds, 2005). When students begin their post-secondary study, EFs are highly in demand (Drigas & Karyotaki, 2019). During this transition, the burden of gathering information, organizing and planning learning, and obtaining accommodations and assistance changes from special educators and parents to SWDs themselves (Stathopoulou et al., 2019). Students who are transitioning to and pursuing postsecondary STEM studies frequently report struggles with time management, making plans, completing assignments, organizing tasks, and maintaining or shifting focus from one task to another. Students must comprehend how to maximize their learning and how to adapt learning strategies across environments; they must also be able to recall and organize knowledge (Morningstar et al., 2017). Essential cognitive and behavioral methods to the learning process may include how to seek information, take notes, plan and organize learning tasks, and use accessible learning resources. Individuals with disorders such as attention deficit/hyperactivity disorder (ADHD), learning disabilities (LD), autism spectrum disorder (ASD), depression, or other forms of brain injury may face EF difficulties (American Psychiatric Association, 2017).

When developing transitional interventions/strategies to support SWDs' success and persistence in postsecondary STEM education, complex factors must be considered, and these complex issues must be framed through an interdisciplinary lens, which broadens the dimensions of understanding and investigating complex issues. Listening to student perspectives and comments is also essential for understanding their learning experiences and identifying their learning requirements among complicated environmental variables. It is critical for intervention and solution creation to have a thorough grasp of an existing issue and to identify students' learning needs. Many studies in the available literature identified research-based approaches to support SWDs' success and perseverance in postsecondary STEM education. Academic mentoring/coaching (e.g., peer-led team learning), technology tools (Hwang; Taylor, 2016), academic counseling (professional perspectives), role models, and work-based learning experiences (Bellman et al., 2014) are some identified practices. It is important to use available research-based evidence and novel technology solutions to meet the learning demands of SWDs in postsecondary STEM education.

Many studies have begun to investigate the integration of research-based practices with cutting-edge technology tools, such as mobile devices and related applications, to support cognition development, emotion regulation, communication, and collaboration with students with disabilities (Kefalis et al., 2020). Certain aspects of mobile devices, such as portability, low cost, and widespread distribution, have the potential to overcome the constraints of face-to-face coaching, such as producing quick feedback and benefits (Drigas; Mitsea, 2022). Individuals with impairments can demonstrate their capabilities when they have access to appropriate learning environments, say Basham et al. (2015). Sowers et al. (2012), for example, recognized electronic mentoring (e-mentoring) as an effective technique for improving the retention, perseverance, and graduation of minority postsecondary SWDs in STEM majors. The researchers employed a user-centered method to determine the usefulness of standard calendar software in supporting cognitive processes and emotional regulation in people with brain injuries (Demertzi et al., 2018). Individuals with cognitive limitations may benefit from generic electronic devices such as personal data assistants (PDA). Mobile technologies have the ability to assist active learning by influencing motivation, engagement, communication, and cooperation. Mobile applications, such as WhatsApp, have evolved into a shared platform that improves accessibility, encourages cooperation, and strengthens incentive to actively participate in academic learning (Chipunza, 2013). Many studies use the terms "mentoring" or "academic coaching" interchangeably (Koch, 2016).

Since the introduction of the iPhone in 2007, mobile technology has gotten a lot of attention in research and practice to enhance active learning in formal and informal K-16 educational settings (Xie et al., 2018). Parker & Boutelle (2009) conducted one study on EF coaching to promote the development of abilities, methods, and beliefs in order to meet the EF problems of SWDs in post-secondary STEM education. SWDs showed that mentorship (i.e., advocacy, emotional support, learning strategies) from the campus disability services office was the most beneficial in enhancing their post-secondary support in one study on student views of services in college (Drigas et al., 2005). However, there are few empirical researches that study the design of academic coaching using mobile devices to assist EF development.

3. Materials and Methods

3.1 Empowering Executive Functions of typical students with ER

During ER-Lab activities, children had to plan and provide the necessary commands to Bee-Bot while also observing the rules and waiting their time. As a result, ER-Lab tasks may have favored the ability to inhibit motor responses, as measured by the Little Frogs test, and control cognition and attention interference, as measured by the Inhibition test, which revealed that a lower number of self-correcting responses in a naming task was significantly related to increased ability to plan complex visuospatial pathways with Bee-Bot. It is possible that the Little Frogs and Inhibition tests differ from the Pippo Says test, which revealed no training benefit, in that they involve more child autonomy in selective and sustained attention. At the pre-training evaluation, a ceiling effect was discovered in the simpler condition of the Pippo Says task, which was consistent with this theory (Di Lieto et al., 2017; Drigas et al., 2005).

These findings, in part, confirm the findings of the previous study (Di Lieto et al., 2017), which showed improved performance in visuospatial working memory and inhibition, and are also consistent with recent literature on EF interventions in childhood, which shows that increasingly challenging working memory and inhibition exercises are critical for cognitive development (Lytra & Drigas, 2021). Furthermore, these two EF components are frequently impaired in neurodevelopmental disorders such as attention deficit hyperactivity disorder, specific learning disabilities, autism spectrum disorders, and cerebral palsy (Lytra; Drigas, 2021; Mitsea, et al., 2020). They are referred to as "tools for learning" because they may represent early developing crossmodal basic processes that influence subsequent development of superior cognitive functions (Drigas; Dourou, 2013) and academic skill acquisition (Van de Weijer-Bergsma et al., 2015).

The papers provide quantitative evidence for the positive effects of ER-Lab activities on EFs, particularly working memory and inhibition, and support the use of ER-Lab as an evidence-based methodology to improve EFs in the early school years (Diamond; Ling, 2016). Methodologically, ER-Lab may be somewhere between telerehabilitation (Grunewaldt et al., 2013) and play-based techniques as a valid tool for improving EFs during childhood. Furthermore, our findings point to the relevance of early intervention and the potential for implementing this type of training in the classroom to directly improve school performance and aid children with EF deficiencies in an ecological, inclusive, and social context.

When a technology-based intervention used computational processes to accomplish activities in the real world, such as with the educational robotics method, a group of studies appeared to be more promising in terms of EF improvements (Marzocchi et al., 2020). That is, instructional robotics employs programming techniques used to manipulate concrete objects (i.e., robots) in order to speculate and test the effects of such manipulation. These approaches aim to foster not only academic skills, but also domain-general skills like planning, problem-solving, and metacognitive abilities. In our study, this technique produced results in both school-aged and pre-school-aged children, as well as special needs groups. A comparable strategy resulted in significantly enhanced planning and inhibitory skills (Marzocchi et al., 2020).

3.2 Empowering Executive Functions of atypical students with ER

The current study discovered that ER-Lab training had a significant effect on inhibition skills in a group of children with special needs (SN), indicating that it is possible to empower one of the main EFs components in children with SN within an ecological context, incorporating social, emotional, and cognitive implications. Because of its technological characteristics, adaptability and flexibility of interfaces, and expanding pedagogical application, the ER-Lab for EFs within schools looked to be a good instrument for this goal (Di Lieto et al., 2017b, 2019). This was the first attempt to use a rigorous and scientific strategy, both in terms of research design and intervention methods, to improve EFs by ER in a sufficiently significant sample of children with SN.

The ER-Lab logbook observations suggested that, first and foremost, despite the great range of clinical problems in the sample, all children had a high level of interest and enthusiasm during ER activities, and all, except one, completed ER-Lab within small groups of children. According to qualitative assessments by teachers, this environment has been important in promoting social inclusion and more efficient learning. Mutual concrete and verbal feedback among children aided in the gradual development of self-control capacities and thorough reflection on pre-set goals to assess the need for adjustment or alterations. Furthermore, the various methodological and goal adjustments were structured according to the type of neuropsychological or cognitive deficiencies in order to promote gradual and efficient learning while taking into account the individual strengths and limitations of children with SN (Chaidi; Drigas, 2020; Chaidi et al., 2021).

The main finding of this study was that ER-Lab training had a significant effect on inhibition skills in terms of speed of processing (Time in Inhibition condition test) and rapid automatization naming in terms of speed of processing and accuracy (Time and Self-correcting responses in Naming condition test). Thus, after training, children with SN demonstrated a significant increase in the speed of their cognitive control of inappropriate responses and the number of self-monitoring responses they displayed in comparison to the pretraining assessment; this was for the improvement of performances of the Self-correcting responses parameter in the Naming condition test (Mitsea et al., 2020).

4. Results and Discussion

4.1 Individual Success in Secondary STEAM Education: EF Challenges

The ability to handle complicated goal-directed actions and intentional tasks in daily life is classified as an EF (Drigas; Karyotaki, 2019). Diamond (2013) developed a three-factor model of executive functions in which inhibition, working memory, and cognitive flexibility collaborate to influence higher-order executive functions such as thinking, planning, and problem solving. EFs have been shown to predict outcomes throughout life, including school academic achievement and workforce performance, physical health, quality of life, job success and marital harmony (Best et al., 2011). Individuals acquire EFs from adolescence through early adulthood. EF have been linked to human performance, notably cognitive flexibility, appropriate action management, formulating and implementing plans, working memory, self-monitoring, and emotional and behavioral control (Drigas; Karyotaki, 2019). People with EF challenges face difficulties in a variety of life domains and areas of functioning, including academic, social, occupational, and psychological areas (Weyandt et al., 2013).

EF inadequacies are a substantial obstacle to success and persistence for SWDs in secondary STEM education (Bellman et al., 2015). Transitioning to and pursuing college studies in secondary and post-secondary STEM education includes consistently demonstrating a difficulty to manage time, develop plans, complete projects, organize tasks, and retain or transfer focus from one topic to another (Drigas et al., 2021). Individuals with a variety of disabilities may confront EF issues in postsecondary education. For example, most existing data indicates that individuals with ADHD and/or LD may have a variety of EF issues in postsecondary educational settings (Parker; Boutelle, 2009). Academic procrastination (Drigas; Papoutsi, 2021), a lack of proper preparation in academic work, poor organization, difficulty with time management and study abilities (Drigas; Karyotaki, 2016), and increased academic stress (Hyman et al., 2006) are among the challenges. According to studies, EF problems for college students with ADHD and LD may lead to lower retention rates and lower educational and vocational attainment compared to peers without disabilities (Murphy et al., 2002). Students with Autism Spectrum Disorder (ASD) may also have EF impairments. Individuals with brain damage/lesions, or other neurological worsening, (e.g., traumatic brain injuries, stroke, Parkinson's disease) and those with limitations in functioning and adaptive behavior (Bak et al., 2008) face EF challenges.

The college experience is a crucial transitional step for all students, but notably for SWDs with EF deficiencies, due to the increasing responsibility and autonomy required with less structure and support (Parker; Boutelle, 2009). College students who require assistance throughout these life transition periods should be considered and provided with tailored support. Morningstar et al. (2017) emphasized the value of assistance in inclusive transition environments. It was critical to give students with access to general learning assistance and tactics, such as teaching learning strategies across grade levels to prepare students for college and career preparedness. However, there was a significant gap between the available customizable academic assistance and services from post-secondary educational settings and matching the tailored needs of SWDs to be academically successful.

4.2 Currently executive functioning help for students with ADHD and disabilities

Researchers have begun to do EF research to assist students with ADHD, LD, and/or other sorts of disabilities in postsecondary education (Parker et al., 2011). In general, academic coaching or EF coaching can be used to provide EF support. According to Robinson & Gahagan (2010), academic coaching is a "one-on-one interaction with a student focusing on strengths, goals, study skills, engagement, academic planning, and performance." EF coaching is characterized as a sort of academic coaching that "provides support for the development of skills, strategies, and beliefs needed to manage executive function challenges" (Parker; Boutelle, 2009). Academic coaching stresses an "inquiry" paradigm of inquiring rather than telling (Bakola; Drigas, 2020). During the coaching process, students can learn from the modeling of effective EF and build their own ideas as their competence improves in clarifying, formulating realistic plans, and taking action on goals based on increased self-awareness of their thinking and actions. Many studies utilized the terms "mentoring" or "academic coaching" interchangeably (Koch, 2016).

The author used the Universal Design for Learning (UDL), (Cast, 2011) framework to guide a review of existing empirical studies on supporting EFs for those students in post-secondary STEM education. This review is structured specifically from an awareness of empirical studies on EF coaching to support SWDs in postsecondary STEM education. Following the first analysis, which identified the limits of traditional EF coaching, the researcher did a second study to better understand the current studies on leveraging technology to help EF coaching for SWDs. This evaluation of the literature influenced the development and creation of a mobile EF coaching solution for SWDs in postsecondary STEM.

According to the findings of this study, motor-based cognitive rehabilitation improves attention and concentration in children with ADHD. Motor activities and cognitive training raise norepinephrine and dopamine levels in the brain, which are important in the attention and thinking systems. As a result, by combining motor exercises and tasks based on strengthening sustained attention with a focus on cognitive tasks, this intervention can have a significant effect on norepinephrine and dopamine in the brains of these children, reducing distraction while improving sustained attention. This finding is consistent with (Drigas et al., 2022) study on the effectiveness of cognitive treatment in enhancing sustained attention in children with ADHD. In addition, Milton (2010) found that computer program training improved working memory and cognitive flexibility in children with ADHD and learning difficulties. The current study's findings were compatible with those of Tajik Parvinchi et al. (2014). Another study found that playing cognitive computer games could help children with ADHD improve their working memory, attention, and cognitive flexibility (Doulou; Drigas, 2022).

In another study, a computer-based cognitive rehabilitation program significantly boosted processing speed, cognitive flexibility, verbal predictive memory scores, and vision, consequently playing an important role in enhancing the activity of the forehead cortex (Chaidi et al., 2021). Numerous researchers investigated the effects of video and computer game training on the cognitive flexibility of children with ADHD, with the results indicating that video and computer game training improved executive functions and flexibility (Abdi et al., 2014). After computer-based cognitive rehabilitation training sessions, children with ADHD have increased mental flexibility, processing speed, anatomical memory, and forehead cortical activation.

4.3 EF's contribution to Academic success

Previous research has revealed that EF is a predictor of Academic Achievement (AA). However, investigations indicating the link between EF and AA have mostly been conducted on children's samples, with only a few studies on adolescents (Dubuc et al., 2020). As a result, our work makes an important contribution in this regard. Our findings suggest that EF deficits (as measured by the BRIEF-2, where high scores indicate EF difficulties) are negatively linked with AA. As a result, students with EF deficiencies earned a lower AA than students with a high degree of EF, and this occurred in each of the individual classes, whether considering the mean of the instrumental classes, or when evaluating the Overall AA. These findings are consistent with previous empirical investigations that suggest that the presence of EF impairments contributes to academic challenges that may impede AA achievement (Bouzaboul et al., 2020).

Given that EF comprises the ability to guide one's attention and conduct toward achieving a goal, these abilities are required to complete most academic tasks (Morgan et al., 2019). As a result, independent of the precise class that the student is in, academic work implies strong demands on the student's EF. It is necessary to plan study time, maintain one's attention, inhibit distracting stimuli that are external to the task at hand, inhibit non-relevant information, select the most important information to recall and remember by using strategic revising techniques, relate information with other pieces of information, and so on. Furthermore, especially in class, it is required to perform multiple things at the same time: Pay attention to and select the most relevant information that the teacher may be delivering through various means (visual and audio), while taking notes on everything. All of these challenges necessitate the use of EF, and they are all required in the school context, regardless of the subject or the content being studied. Previous study has shown that students with greater EF have better skills to benefit from formal and informal learning opportunities, and hence achieve higher AA than students with lower EF (Burns et al., 2018).

Thus, the findings of our study (EF contributes to all AA measures) offer an additional contribution to the limited information known on EF and AA in adolescents, pointing in the same direction as the findings for younger students. The findings are consistent with those of other writers, implying that EF is domain-general and necessary in a variety of academic skills (Dubuc et al., 2020; Morgan et al., 2019). However, this does not allow us to exclude the concept that EF is domain-specific and that each EF component is associated differentially to AA (Purpura et al., 2017), because we did not analyze the diverse components of EF independently in our research. As we discuss further below, this is one of our study's shortcomings and an issue that may be addressed in future investigations. However, our investigation advances in that it examined the relationship between FE and AA beyond the disciplines of Language and Mathematics, including AA for hitherto unstudied classes.

Given that EF helps explain some of the variability in adolescents' AA, therapies aimed at improving EF should incorporate AA improvements. As a result, strengthening students' EF should be a priority throughout the educational context, especially given that EF's significance extends beyond its effect on AA. A lack of EF during adolescence may result in insufficient AA and difficulties facing and regulating the physical, psychological, and social changes that occur during this life stage (Morgan et al., 2019). As a result, the significance of EF extends beyond the academic setting and affects the student's quality of life and ability to contribute to societal advancement. Because we know that EF are particularly sensitive to contextual influences during adolescence, and because interventions are more effective the earlier they are implemented, this life stage should be considered to ensure its improvement. As a result, several activities and interventions have been proven to be useful in boosting EF (Diamond et al., 2016). However, there is currently a paucity of information on which precise components of the training regimen have the greatest effects and on what type of participants, particularly in the adolescent population, given that most studies in this field have concentrated on preschoolers. As a result, we are uninformed of the frequency, duration, intensity, and so on of the intervention in order to ensure the maximum results, based on the specific features of the persons receiving the intervention: age, gender, motivation for the training tasks, beginning FE level, and so on. Additional fine-tuned analysis assessing individual differences are required to discover for whom each instruction works.

5. Conclusion

Finally, this study may indicate fresh and intriguing aspects concerning the instructional role of robots in the scholastic system, including in children with ADHD. Because of the group setting of the ER exercises, these activities may promote both cognitive learning and social inclusion. The current study's findings support the usage of robotics-based educational systems to stimulate the use of specific cognitive and attention talents. This study backs up the premise that Educational Robotics activities have an impact on executive functions since they may be used to build higher-level control components including forecasting, planning, and problem solving. Indeed, this study provides quantifiable data for analyzing the effects of a robotics laboratory on children's transversal high-level cognitive abilities. In general, the findings revealed that participation and improvement of logical reasoning ability enable participants to foresee and plan the sequence of activities required to complete a certain behavioral task.

6. Acknowledgments

Thanks to the team of the Net Media Lab, in the framework of the National Centre For Scientific Research Demokritos (NCSR), for their support in the conducted research.

7. Author's Contributions

Conceptualization, N.D., and A.D.; Formal analysis, N.D., and A.D.; Investigation, N.D., and A.D.; Methodology, N.D., and A.D.; Supervision, A.D.; Validation, A.D.; Writing—original draft, N.D.; Writing—review and editing, N.D., and A.D. All authors have read and agreed to the published version of the manuscript.

8. Conflicts of Interest

The authors declare no conflict of interest.

9. Ethics Approval

Not applicable

10. References

Abdi, A., Arabani Dana, A., Hatami, J., & Parand, A. (2014). The Effect of cognitive computer games on working memory, attention and cognitive flexibility in students with attention deficit/hyperactivity disorder. *Journal of Exceptional Children*, 14(1), 20-33.

American Psychiatric Association blog (2017). Executive Function of the Brain: Key to Organizing, Managing Time and More. Retrieved from https://www.psychiatry.org/news-room/apa-blogs/apa-blog/2017/01/executive-functionof- the-brain-key-to-organizing-managing-time-and-more

Bakola, L., & Drigas, A. (2020). Technological development process of emotional Intelligence as a therapeutic recovery implement in children with ADHD and ASD comorbidity. *International Journal of Online & Biomedical Engineering,* 16(3), 75-85. https://doi.org/10.3991/ijoe.v16i03.12877

Basham, J. D., Stahl, S., Ortiz, K., Rice, M. F., & Smith, S. (2015). Equity matters: Digital & online learning for students with disabilities. Lawrence, KS: *Center on Online Learning and Students with Disabilities*.

Bellman, S., Burgstahler, S., & Hinke, P. (2015). Academic Coaching: Outcomes from a Pilot Group of Postsecondary STEM Students with Disabilities. *Journal of Postsecondary Education and Disability,* 28, 103-108.

Bellman, S., Burgstahler, S., & Ladner, R. (2014). Work-based learning experiences help students with disabilities transition to careers: *A case study of University of Washington projects*, Work, 48(3), 399-405.

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and individual differences*, 21(4), 327-336.

Bak, M., Krabbendam, L., Delespaul, P., Huistra, K., Walraven, W., & van Os, J. (2008). Executive function does not predict coping with symptoms in stable patients with a diagnosis of schizophrenia. *BMC psychiatry*, 29, 8-39.

Bouzaboul, M., Amri, A., Abidli, Z., Saidi, H., Faiz, N., Ziri, R., & Ahami, A. (2020). Relationship between Executive Functions and Academic Performance among Moroccan Middle School Students.

Dement. Neuropsychol., 14, 194–199.

Burns, R.D., Fu, Y., & Brusseau, T.A., Clements-Nolle, K., & Yang, W. (2018). Relationships among Physical Activity, Sleep Duration, Diet, and Academic Achievement in a Sample of Adolescents. Prev. Med. Rep., 12, 71–74.

Cast (2011). Universal Design for Learning (UDL) Guidelines Version 2.0.

Chaidi, I., & Drigas, A. (2020). Parents' Involvement in the Education of their Children with Autism: Related Research and its Results *International Journal Of Emerging Technologies In Learning*, (IJET) 15 (14), 194-203. https://doi.org/10.3991/ijet.v15i14.12509

Chaidi, E., Kefalis, C., Papagerasimou, Y., & Drigas, A. (2021). Educational robotics in Primary Education. A case in Greece, 10 (9). https://doi.org/10.33448/rsd-v10i9.16371

Chipunza, P. R. C. (2013). Using mobile devices to leverage student access to collaboratively generated resources: A case of WhatsApp instant messaging at a South African University. *International Conference on Advanced Information and Communication Technology for Education*.

Demertzi, E., Voukelatos, N., Papagerasimou, Y., & Drigas, A. (2018). Online learning facilities to support coding and robotics courses for youth. *International Journal of Engineering Pedagogy* (iJEP), 8(3), 69-80.

Di Lieto, M. C., Inguaggiato, E., Castro, E., Cecchi, F., Cioni, G., Dell'Omo, M., et al. (2017). Educational robotics intervention on executive functions in preschool children: A pilot study. *Comput. Hum. Behav*. 71, 16–23. https://doi.org/10.1016/j.chb.2017.01.018

Di Lieto, M. C., Pecini, C., Castro, E., Inguaggiato, E., Cecchi, F., Dario, P., et al. (2019). "Robot programming to empower higher cognitive functions in early childhood," in Smart Learning with Educational Robotics, *ed. L. Daniela, (Cham: Springer),* 229–250. https://doi.org/10.1007/978-3-030-19913-5

Diamond, A. (2013). Executive functions. *Ann. Rev. Psychol*. 64, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. Dev. *Cogn. Neurosci*, 18, 34–48. https://doi: 10.1016/j.dcn.2015.11.005

Doulou, A., & Drigas, A. (2022). Electronic, VR & Augmented Reality Games for Intervention in ADHD *Technium Social Sciences Journal*, 28, 159. https://doi.org/10.47577/ tssj.v28i1.5728

Drigas, A.S., Vrettaros, J., Koukianakis, L.G. & Glentzes, J.G. (2005). A Virtual Lab and e-learning system for renewable energy sources. *Int. Conf. on Educational Tech.*

Drigas, A., & Dourou, A. (2013). A Review on ICTs, E-Learning and Artificial Intelligence for Dyslexic's Assistance. *iJet*, 8(4), 63-67.

Drigas, A., & Karyotaki, M. (2017). Attentional control and other executive functions. *Int J Emerg Technol Learn* iJET 12(3), 219–233

Drigas, A., & Karyotaki, M. (2019). Executive Functioning and Problem Solving: A Bidirectional Relation. *International Journal of Engineering Pedagogy* (iJEP) 9(3), 76-98.

Drigas, A., Papoutsi, C., & Skianis. (2021). Metacognitive and Metaemotional Training Strategies through the Nine-layer Pyramid Model of Emotional Intelligence. *International Journal of Recent Contributions from Engineering, Science & IT* (iJES), 9(4) 58-76. https://doi.org/10.3991/ijes.v9i4.26189

Drigas, A., & Mitsea, E. (2022). Conscious Breathing: a Powerful Tool for Physical & Neuropsychological Regulation. *The role of Mobile Apps Technium Social Sciences Journal* 28, 135-158. https://doi.org/10.47577/tssj.v28i1.5922

Drigas, A., Mitsea, E., & Skianis, C. (2022). Clinical Hypnosis & VR, Subconscious Restructuring-Brain Rewiring & the Entanglement with the 8 Pillars of Metacognition X 8 Layers of Consciousness X 8 *Intelligences. International Journal of Online & Biomedical Engineering* (IJOE) 18 (1), 78-95. https://doi.org/10.3991/ijoe.v18i01.26859

Dubuc, M.-M., Aubertin-Leheudre, M., & Karelis, A.D. (2020). Relationship between Interference Control and Working Memory with Academic Performance in High School Students: *The Adolescent Student Academic Performance Longitudinal Study (ASAP)*. J. Adolesc, 80, 204–213.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychol. Bull*, 134:31. https://doi.org/10.1037/0033-2909.134.1.31

Grunewaldt, K. H., Løhaugen, G. C. C., Austeng, D., Brubakk, A.-M., & Skranes, J. (2013). Working memory training improves cognitive function in VLBW preschoolers. *Pediatrics* 131, 747–754. https://doi.org/10.1542/peds.2012-1965

Hwang, J., & Taylor, J. C. (2016). Stemming on STEM: A STEM education framework for students with disabilities. *Journal of Science Education for Students with Disabilities*, 19, 39-49.

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: a systematic review and re-analysis of latent variable studies. *Psychol. Bull*. 144:1147. https://doi.org/10.1037/bul0000160

Kefalis, C., Kontostavlou, EZ., & Drigas, A, (2020). The Effects of Video Games in Memory and Attention. *Int. J. Eng. Pedagog*. (IJEP) 10 (1), 51-61. https://doi.org/10.3991/ijep.v10i1.11290

Koch, A. (2016). Project iCAN: A STEM learning and persistence model for postsecondary students with disabilities. *University of Central Florida. Orlando, FL*.

Lytra, N., & Drigas, A. (2021). STEAM education-metacognition–Specific Learning Disabilities *Scientific Electronic Archives* 14 (10). https://doi.org/10.36560/141020211442

Miller, M. R., Giesbrecht, G. F., Müller, U., McInerney, R. J., & Kerns, K. A. (2012). A latent variable approach to determining the structure of executive function in preschool children. *J. Cogn. Dev.* 13, 395–423. https://doi.org/10.1080/ 15248372.2011.585478

Mitsea, E., Lytra, N., Akrivopoulou, A., & Drigas, A. (2020). Metacognition, Mindfulness and Robots for Autism Inclusion. Int. *J. Recent Contributions Eng. Sci. IT* 8 (2), 4-20.

Milton, H. (2010). Effects Of A Computerized Working Memory Training Program On Attention, Working Memory, And Academics, In Adolescents With Severe ADHD/LD, *psychology journal*, 1(14), 120 – 122.

Morgan, P.L., Farkas, G., Wang, Y., Hillemeier, M.M., Oh, Y., & Maczuga, S. (2019). Executive Function Deficits in Kindergarten Predict Repeated Academic Difficulties across Elementary School. *Early Child. Res*. Q., 46, 20–32.

Morningstar, M. E., Zagona, A. L., Uyanik, H., Xie, J., & Mahal, S. (2017). Implementing College and Career Readiness: Critical Dimensions for Youth With Severe Disabilities. *Research and Practice for Persons with Severe Disabilities*, 42 (3). https://doi.org/10.1177/1540796917711439

Murphy, K. R., Barkley, R. A., & Bush, T. (2002). Young adults with attention deficit hyperactivity disorder: subtype differences in comorbidity, educational, and clinical history. *The Journal of nervous and mental disease*, 190(3), 147-157.

Parker, D. R., Hoffman, S. F., Sawilowsky, S., & Rolands, L. (2011). An Examination of the Effects of ADHD Coaching on University Students' Executive Functioning. *Journal of Postsecondary Education and Disability*, 24(2), 115-132.

Parker, D. R., & Boutelle, K. (2009). Executive Function Coaching for College Students with Learning Disabilities and ADHD: *A New Approach for Fostering Self-Determination. Learning Disabilities Research & Practice*, 24(4), 204-215.

Purpura, D.J., Schmitt, S.A., Ganley, C.M. (2017). Foundations of Mathematics and Literacy: The Role of Executive Functioning Components. *J. Exp. Child Psychol*., 153, 15–34.

Robinson, C., & Gahagan, J. (2010). Coaching students to academic success and engagement on campus. *About Campus*, 15(4), 26-29. https://doi.org/10.1002/abc.20032

Romine, C. B., & Reynolds, C. R. (2005). A model of the development of frontal lobe functioning: Findings from a meta-analysis. *Applied neuropsychology*, 12(4), 190-201.

Stathopoulou, A., Karabatzaki, Z., Tsiros, D., Katsanton,i S., & Drigas, A. (2019). Mobile apps the educational solution for autistic students in secondary education. *Journal of Interactive Mobile Technologies (IJIM)* 13 (2), 89-101. https://doi.org/10.3991/ijim.v13i02.9896

Sowers, J.-A., Powers, L., Schmidt, J., Keller, T. E., Turner, A., Salazar, A., & Swank, P. R. (2017). A Randomized Trial of a Science, Technology, Engineering, and Mathematics Mentoring Program. *Career Development and Transition for Exceptional Individuals*, 40(4), 196-204. https://doi.org/10.1177/2165143416633426

Tajik-Parvinchi, D., Wright, L., & Schachar, R. (2014). Cognitive rehabilitation for attention deficit/hyperactivity disorder (ADHD): Promises and problems. Journal of the Canadian Academy of Child and Adolescent Psychiatry, *Journal de l'Académie canadienne de psychiatrie de l'enfant et de l'adolescent,* 23(3), 207–217.

Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Dev. Sci*. 12, 106–113. https://doi.org/10.1111/j.1467-7687.2008.00745.x

Usai, M. C., Viterbori, P., Traverso, L., & De Franchis, V. (2014). Latent structure of executive function in five- and six-year-old children: a longitudinal study. *Eur. J. De. Psychol*. 11, 447–462. https://doi.org/10.1080/17405629.2013.840578

Van de Weijer-Bergsma, E., Kroesbergen, E. H., & Van Luit, J. E. H. (2015). Verbal and visual-spatial working memory and mathematical ability in different domains throughout primary school. *Mem. Cogn*. 43, 367–378. https://doi.org/10.3758/ s13421-014-0480-4

Weyandt, L., DuPaul, G.J., Verdi, G., Rossi, J.S., Swentosky, A.J., Vilardo, B.S., & Carson, K.S. (2013). The performance of college students with and without ADHD: Neuropsychological, academic, and psychosocial functioning. *Journal of Psychopathology and Behavioral Assessment*, 35, 421–435.

Xie, J., Basham, J. D., Marino, M. T., & Rice, M. (2018). Reviewing research on mobile learning for students with and without disabilities in k-12 educational settings. *Journal of Special Education Technology,* 33. 1647-1664. https://doi.org/10.1177/0162643417732292

Funding

Not applicable.

Intitutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.