How to train executive functions through classroom activities in kindergarten

It is important for teacher training programs to include information about early EF training and for educators of young children to understand EF training.

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Executive Summary

Executive functions (EFs) are a group of cognitive functions (working memory, inhibitory control, flexibility) that are necessary for the cognitive control of behavior.

EFs can be trained: lab training showed improvements in EFs and brainwave changes as neural correlates of those improvements.

A number of kindergarten curricula have been shown to improve EFs.

Not all curricula train EFs. The most effective ones involve repeated activities that are not too easy or too difficult, in which the requirements of EFs are increased when possible, depending on performance.

Including EF training through curricula can be beneficial for kindergarten children's cognitive development, especially for disadvantaged children.

It is important for teacher training programs to include information about early EF training and for educators of young children to understand EF training.

Executive functions (EFs)

What are the cognitive and emotional abilities that children need to be successful in school and life? Tomorrow's adults will need a high level of proficiency in their executive functions (EFs), a group of cognitive processes necessary for the cognitive control of behavior[1] (Diamond, 2013). Just as an air traffic control system at a busy airport safely manages the arrivals and departures of many aircraft on multiple runways, we need this EF skill set to filter distractions, prioritize tasks, set and achieve goals, and control impulses[2]. In this brief, "executive functions" and "self-regulation skills" are treated as synonyms because both depend on working memory, inhibitory control, and mental flexibility. There is some agreement that these are three basic components of EFs[3]. These components (and their neural bases) are described in detail in another brief in this series (https://solportal.ibe-unesco.org/articles/executive-function/). This brief focuses on training EF skills in the kindergarten classroom.

It is important to develop EF skills because they are building blocks for later academic achievement, socioemotional adaptation, and general well-being (https://solportal.ibe-unesco.org/articles/executive-function/). Therefore, it is a desirable objective of kindergarten to promote the development of EFs. In fact, some kindergarten curricula include EF skill development as an explicit objective (e.g., [4]). This objective may be particularly significant for children growing up in poverty, for two reasons. First, poor children's EF achievements tend to be lower than their more wealthy peers' when entering kindergarten[5]. Factors associated with living in poverty (for example, higher stress, lower parental education, and fewer educational resources available) are also associated with lower scores on EF tasks. Second, lower socioeconomic status children tend to benefit the most from interventions aimed at EF training (e.g., [6]). Indeed, in studies that have reported positive effects of EF training, the training was more (and sometimes only) beneficial for disadvantaged children or children with lower EF development[7]. Thus, knowing how to improve EFs in kindergarten classrooms seems to be important for all educators and policymakers, but especially for those working with poor children.

EF training outside the curriculum

Before looking at some curricular studies, it is important to note that research studies involving other forms of EF training have confirmed that EFs are trainable. Numerous outside-the-classroom studies have reported improvements in EFs in young children after training, most using computerized EF training programs (for example, 8-10). For example, in a study conducted in Sweden[10], 4- and 5-years old children were divided into four groups: one of them received computerized working memory training, the second one received inhibitory control training, the third one played computerized games requiring low EF and the fourth group did not receive any intervention. All children were evaluated before and after the training or control activities various with EF tests. Activities in all groups lasted 15 minutes a day for 5 weeks and working memory, as well as inhibitory control training, consisted in games that continuously adapted the difficulty to each child's performance: three correct trials were required in order to advance to the next level. Results showed that working memory training improved children's scores in all working memory tasks significantly more than the control groups; also, children in the inhibitory control group improved their inhibition scores in two out of three tasks more than controls.

In addition to evidence for change in EF behaviors with outside-the-classroom training in young children, there is some evidence for change in EF-related neural processing. One study[11] measured the behavioral and neural impact of a laboratory computerized cognitive training program based on promoting reflection on a computerized version of a widely used cognitive flexibility task (named Dimensional Change Card Sort). The task requires classifying draws according to one rule (e.g., color) and later flexible change to classify according to a second rule (e.g., shape), inhibiting the first rule. A group of 18 preschoolers played one session of that while receiving reflection training (consisting of questions to think about the rules of the game); two comparison groups of 16 and 17 children received also one session of corrective (i.e., "right/no") or no feedback at all. After those activities, a change in a brainwave measure of inhibitory control (called the reduction of the N2 amplitude) was seen only in the reflection training group, not in the comparison group. Also, children in the reflection training group improved their scores in the game significantly more than the other groups. In sum, this study shows there is neuroplasticity associated with EFs improvements.

EF training as part of the curriculum

The Tools of the Mind curriculum for preschoolers[12] includes numerous brief activities that were designed, in theory, to promote EF development. For example, activities encourage students to tell oneself out loud what one should do. This is also known as "private speech", an important component of planning[13]. The curriculum also includes dramatic play, which requires a child to remember the role they will play while playing it (thereby using the EF working memory) without becoming distracted (thereby using the EF inhibitory control), and to adapt to the contingencies of the play (thereby using the EF flexibility). The dramatic play activities include the use of aids to facilitate memory and attention; for example, when children have to listen to a story, they are shown an image of an ear to help them to remember that they need to be listening.

The Tools of the Mind curriculum has been tested in research studies to see if it does actually affect the development of children's EF skills. For example, in one study, the curriculum was implemented by regular teachers, in regular low-income schools in the US[14]. The teachers spent 80% of each day promoting EF skills through the curriculum because the training was embedded in most classroom activities[14]. Classrooms with a total of 147 preschoolers were divided into two groups: About half of the classrooms used the Tools of the Mind curriculum for a school year, while the other half used a curriculum focused on literacy. EF skills were measured at the beginning and end of the school year with two computerized tasks (called the Dots task and the Flanker task, both of which are unlike any of the classroom activities so it could not be claimed that some children had been trained directly on these tasks). These tasks address working memory, inhibition, and flexibility. Children who had learned with the Tools of the Mind curriculum significantly outperformed children who had learned with the literacy curriculum across the most demanding conditions in both tasks; that is, differences between groups became evident only when EFs were hardly challenged. It is probably reflecting that various curricula demand EFs to some extent but only some of them strongly demand EFs.

Another study analyzed whether the Tools of the Mind curriculum changes not only children's EF behaviors but also their neuroendocrine functioning (that is, hormone levels)[15]. In this study, researchers divided 79 classrooms (including 759 kindergarteners) from poor schools in the US into two groups: one receiving the Tools of the Mind curriculum and the other receiving regular education for a school year. Measuring hormone levels through samples of saliva, the researchers found higher levels of one hormone (cortisol) and lower levels of another hormone (alpha-amylase) in children in the classrooms implementing Tools of the Mind at the end of the year – but only in high-poverty schools; the effect was not seen in medium-poverty schools. Measuring behavior through standardized tasks and tests, the researchers also found that children in the Tools of the Mind classrooms showed better EF performance and higher scores on language and mathematics tests, in comparison with children receiving regular education. The researchers conducting the study interpreted these results as positive effects of Tools of the Mind on children's stress response physiology (physiological support for engagement in learning activities), EF skill development, and academic skill development.

Beyond Tools of the Mind, other curricula have also been shown to affect the development of EF skills. For example, a study conducted in the US involving 2,018 four- and five-year-old children found that a prekindergarten curriculum that implemented a coaching system and consistent literacy, language, and mathematics programs produced small improvements on children's EF skills[16].

Another study conducted in Norway found that a structured kindergarten curriculum impacted EF skill development[17]. This study involved 691 five-year-olds in 71 schools who were exposed to a curriculum modeled on a playful learning approach[18] and emphasizing a warm and responsive child-teacher relationship[19] for a school year. In comparison with the comparison group, significant improvements in EFs mathematics and language were observed only in the preschool centers identified as

low-quality at baseline, suggesting that a structured curriculum can reduce inequality in early childhood learning environments.

In addition, use of various other curricula has been associated with improvements in some EF behavioral outcomes in preschoolers (e.g., [20-22]). However, other studies have reported no effects of curriculum on EF development and still others have reported mixed effects (see [23] a critical review on this issue). Further, even the Tools curriculum did not always reach significant positive effects (see [24] for a review). Evidently, not all curricula significantly train EFs, and one curriculum showing positive effects does not guarantee that the same curriculum will be equally effective in another context.

Key aspects of EF training in the classroom

Across studies (e.g., [1,23]), the key characteristics of successful EF training for young children appear to be:

(a) Challenging activities: Activities that train EFs should not be too easy, and not too difficult, to solve.

(b) Practice: Although a limited number of activities can be useful to train EFs, greater improvements were seen for curricula that demand EFs across all activities, offering repeated opportunities for practice[14,20]

(c) When a certain mastery level is reached, EF demands should be incremented: As in any training, the difficulty of the task should be progressively increased across the sequence of activities and/or within the same task for continuous improvement. If EF demand is not incremented, few further gains will be seen[25]. Table 1 shows examples of kindergarten activities designed by teachers and neuroscientists with the aim of training EFs in classrooms[26], with options to increase and decrease EF demand. Thus, EF training is not about a specific exercise, but rather about a way of presenting and solving any exercise[1,23].

Table 1. Examples of kindergarten activities aimed at training EFs, with options to increase and decrease EF demands

Kindergarten classroom activity		EF mainly demanded	Increasing EF demand	Decreasing EF demand
	Students pair up with a deck of cards. Partner #1 flips five cards face up and gives Partner #2 a few seconds to look at them. Then, Partner #2 closes his or her eyes as Partner #1 removes one of the five cards. Finally, Partner #2 opens his or her eyes and has to recall which card is missing.	Working memory (needed to retain all the cards in mind and check which has been removed)	Play with more cards	Play with fewer cards
	Students in whole group dance while they listen to music. When the music stops, children freeze until the music starts playing again.	Inhibitory control (motor inhibition is needed to freeze)	The same activity but with two different songs: when song #1 is being played and then stopped, children have to freeze with hands up; when song #2 is played and then stopped, children have to freeze with hands down	The same activity, but the teacher acts as a model, dancing while the music sounds and freezing when the music stops
	The teacher shows the whole group a letter of the alphabet and children say words starting with the sound represented by that letter (without repeating words); after a while of playing that way, the rules of the game change: now children say words that end with the sound represented by the letter.	Flexibility (needed to not keep playing according to the first rule when the rule is changed)	New game: when the letter is drawn in red, children say words starting with that sound; when the letter is drawn in blue, children say words ending with that sound; show blue and red letters randomly	While showing the letter the teacher pronounces the sound associated with it, to help children think of words beginning with that sound

Conclusion

Although kindergarten classroom activities are not the only way to train EF skills[8-10], they can be an effective way[14,16]. Training EFs in the kindergarten classroom may have some advantages. First, improving EFs early may have increasing benefits over time and may reduce the need for costly special education later[1]. Second, with enough training, it can be done by regular teachers in regular public schools (e.g., [14-17]). Third, no content needs to be replaced to conduct EF training; on the contrary, effective in-classroom training can be embedded in regular language, math, or science curricula[17]. And finally, EF training inside the classroom seems particularly important for disadvantaged children, who tend to show poorer EF skills and tend to benefit the most from EF training[1]. Thus, it is important for teacher training programs to include information about early EF training and for educators of young children to understand EF training.

References

1 Diamond, A. Executive functions. *Annu. Rev. Psychol.* **64,** 135-168 (2013).

2 *Center on the Developing Child at Harvard University*. Building the Brain's "Air Traffic Control" System: How Early Experiences Shape the Development of Executive Function: Working Paper 11. www.developingchild.harvard.edu (2011)

3 Miyake, A. et al. The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cogn. Psychol.* **41**, 49-100 (2000).

4 Dirección General de Escuelas https://www.mendoza.edu.ar/comienza-el-programa-juegos-del-cerebro/ (2022).

5 Blair, C. Executive function and early childhood education. *Curr. Opin. Behav. Sci.* **10**, 102-107 (2016).

6 Karbach J, Kray J. How useful is executive control training? Age differences in near and far transfer of task-switching training. **12**, 978-990 (2009).

7 Scionti, N., Cavallero, M., Zogmaister, C. & Marzocchi, G. M. Is Cognitive Training Effective for Improving Executive Functions in Preschoolers? A Systematic Review and Meta-Analysis. *Front. Psychol.* **10**, 2812 (2020).

8 Bergman Nutley, S., et al. Gains in fluid intelligence after training non-verbal reasoning in 4-year-old children: A controlled, randomized study. *Dev. Sci.* **14**, 591-601 (2011).

9 Holmes, J., Gathercole, S. E. & Dunning, D. L. Adaptive training leads to sustained enhancement of poor working memory in children. *Dev. Sci.* **12**, F9-F15 (2009).

10 Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G. & Klingberg, T. Training and transfer effects of executive functions in preschool children. *Dev. Sci.* **12**, 106-113 (2009).

11 Espinet, S. D., Anderson, J. E. & Zelazo, P. D. Reflection training improves executive function in preschool-age children: Behavioral and neural effects. *Dev. Cogn. Neurosci.* **4**, 3-15 (2013).

12 Bodrova, E. & Leong D. J. Tools of the Mind: The Vygotskian Approach to Early Childhood Education. *Merrill/Prentice-Hall*, New York (2007).

13 Lidstone, J. S., Meins, E. & Fernyhough, C. The roles of private speech and inner speech in planning during middle childhood: Evidence from a dual task paradigm. *J. Exp. Child Psychol.* **107**, 438-451 (2010).

14 Diamond, A., Barnett, W. S., Thomas, J. & Munro, S. Preschool program improves cognitive control. *Science* **318**, 1387-1388 (2007).

15 Blair, C. & Raver, C. C. Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PLoS One* **9**, e112393 (2014).

16 Weiland, C. & Yoshikawa, H. Impacts of a Prekindergarten Program on Children's Mathematics, Language, Literacy, Executive Function, and Emotional Skills. *Child Dev.* **84**, 2112-2130 (2013).

17 Rege, M. et al. Promoting Child Development in a Universal Preschool System: A field Experiment *CESifo* (2019). doi: http://dx.doi.org/10.2139/ssrn.3434830

18 Weisberg, D. S., Hirsh-Pasek, K. & Golinkoff, R. M. Guided Play: Where Curricular Goals Meet a Playful Pedagogy. *Mind Brain Educ.* **7**, 104-112 (2013).

19 Pianta, R. C. *Enhancing Relationships between Children and Teachers. APA*, Washington, DC, US (1999).

20 Lillard, A. & Else-Quest, N. The early years. Evaluating Montessori education. *Science* **313**, 1893-1894 (2006).

21 Röthlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E. & Roebers, C. M. Improving executive functions in 5-and 6-year-olds: Evaluation of a small group intervention in prekindergarten and kindergarten children. *Infant Child Dev.* **21**, 411-429 (2012).

22 Traverso, L., Viterbori, P. & Usai, M. C. Improving executive function in childhood: evaluation of a training intervention for 5-year-old children. *Front. Psychol.* **6,** 525 (2015).

23 Diamond, A. & Ling, D. S. 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 (2016).

24 Baron, A., Evangelou, M., Malmberg, L. E. & Melendez-Torres, G. J. The Tools of the Mind curriculum for improving self-regulation in early childhood: a sytematic review. *Campbell Syst. Rev.* **13**, 1-77 (2017).

25 Klingberg, T. et al. Computerized training of working memory in children with ADHD-a randomized, controlled trial. *J. Am. Acad. Child Adolesc. Psychiatry* **44**, 177-186 (2005).

26 Hermida, M. J. et al. Cognitive neuroscience, developmental psychology, and education: Interdisciplinary development of an intervention for low socioeconomic status kindergarten children. *Trends Neurosci. Educ.* **4**, 15-25 (2015).