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Developing indicators of executive functions in preschool children at 3–4 years in Thailand

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Abstract

The objective of this study was to develop executive function indicators for Thai children aged 3–4 years. The study methodology was designed to improve executive function indicators and assessment tools. The research participants in this study were 389 children from 18 schools in 6 regions of Thailand. The samples were determined using multistage sampling. The instrument used to collect data was an executive function assessment form. Data were analysed using second-order confirmatory factor analysis. Regarding executive functions in preschool children aged 3–4 years, there were 3 components and 9 indicators, consisting of: (1) working memory with 3 indicators: memorizing and recalling, bringing information to use in a timely manner, and linking ideas; (2) inhibitory control with 3 indicators: restrained interests, resisting interference, and suppressing needs; and (3) cognitive flexibility with 3 indicators: adapting behavior, adjusting action plans, and changing needs. The confirmatory factor analysis showed that the model fit the empirical data ($\chi 2 = 27.95$, $df = 21$, p value = .14, ($\chi 2/df = 1.33$, GFI = 0.98, AGFI = 0.97, RMSEA = 0.03, and standardized RMR = 0.02).

Introduction

In the 21st century, our global society has changed, developed and modernized in all aspects such as the economy, society, culture, politics, technology, and public health. People have been affected by these changes and should be equipped with the knowledge and competency needed to live within the changing society. Ngamvirojcharoen (2020) said that what we do today will affect future living. If we want a better life, we need to get ready to deal with the harsh times ahead and deal with unpredictable situations by controlling our emotions, practicing being thoughtful and reasonable and properly acting in relation to them. Hence, it is important to properly develop today's children as they are our country's future destiny. These contexts pose

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challenges to how people live. We must ensure children and youth can safely adapt to the changing environment, learn effectively, and tolerate unfamiliar circumstances.

Executive functions (EFs) are crucial for achieving success in academic life, work, health, and family relationships. Children need to develop these brain function skills from an early age. These skills will provide them with appropriate tools to face challenging situations, helping them to consciously control their thoughts, actions, and emotions. The brain of preschool children develops rapidly. If it is not properly stimulated, or if undesirable behaviours are identified and not corrected from a young age, it can lead to behavioural problems later in life. Examples include social issues such as aggressiveness, drug abuse, dropping out of school, and other related problems (Chutabhakdikul et al., 2017). If there were behavioural assessment tools that indicate EFs, it would help identify problems more precisely. Furthermore, if problematic behaviours are detected during childhood, they are easier to correct compared to other stages of life.

In Thailand, there are very few studies on EFs indicators in preschool children. While foreign countries have already developed EFs behavioural assessment tools, they often include a large number of behavioural indicators that may not be suitable for the context of children in Thailand. Therefore, this study aims to develop indicators of EFs for Thai preschool children aged 3–4 years. This will help create tools for collecting and analysing behavioural data. Ultimately, those tools will lead to the design of classroom learning activities and child-rearing practices that effectively stimulate EF functioning.

Literature Review

This study focuses on developing EF indicators and has conducted a review of relevant literature to create the following conceptual framework:

The Concept of Executive Functions

Executive Functions (EFs) are abilities resulting from the functioning of the frontal lobe. These abilities help control thoughts, emotions, and actions, allowing for appropriate behavioural expression. Goal-directed behaviour refers to behaviour that expresses EFs. Recently, numerous EF skill studies and research involving preschool children have focused on various activities such as storytelling, music and body movement, scientific experiments, creative arts, computerized training, non-computerized games, physical activities and mindfulness training (Diamond & Lee, 2011; Morton, 2013; Sokolovic, 2024). These activities are helpful in supporting and developing children, enabling them to learn by doing, thinking, and solving problems in various situations related to their development.

Currently, scientists have not reached a consensus on all the functions of EF. Hendry et al. (2016) stated that it consists of 4 aspects: attention control, self-regulation, processing speed, and cognitive flexibility. Hargraves (2022) mentioned that it comprises 3 aspects: attention and inhibition, working memory, and cognitive flexibility. Wiebe et al. (2011) suggested that it consists of 2 aspects: working memory, and inhibition. Furthermore, the Center on the Developing Child at Harvard University (2011) suggested that 3–4 year old children needed to use their working memory function of the EF components. This provided children with the ability to memorize 2 rules and follow them. For cognitive flexibility, children should have information to make decisions in different situations. If the data they had did not meet the target, there were alternative methods. To achieve the goals, the children needed to have the ability to recall memories. The ability to resist distractions and impulses while doing tasks leading to goal attainment was inhibitory control. The abilities mentioned above are functions of EFs (Howard & Melhuish, 2017). In summary, 3 components of the executive functions were found in preschoolers. They were: (1) working memory, (2) inhibitory control, and (3) cognitive flexibility. These components formed the basic data leading to improvements in the behavioural indicators.

Working Memory (WM) is composed of various types of behavioural indicators. These include recalling information to use it (Wiebe et al., 2011), memorizing and playing by the rules (Center on the Developing Child at Harvard University, 2011), memorizing pictures and their details (Howard & Melhuish, 2017), storing data in the brain and using it, providing a child with the ability to read, collecting data, recalling it in order to answer questions (The Understood Team, 2021), and managing metacognition indicators (Chutabhakdikul et al., 2017). Additionally, Rangsiyanon et al. (2019) suggested that memorizing data had to be meaningful and that storing the data needed to be done by connecting it to previous experiences in order to process it and use it when needed. It is important to provide a child with a life that has enough information to help them understand things.

Inhibitory Control (IC) allows an individual to repress their impulses and natural, habitual, or dominant behavioural responses to stimuli (Hendry et al., 2016; Phillips-Silver & Daza, 2018; Wiebe et al., 2011). It enables one to think before acting, stop behaviour that is bothering or troubling others, cease muddling, concentrate on tasks, control emotions, and overcome both extrinsic and intrinsic needs and stimuli. All of these abilities help one achieve success (Chutabhakdikul et al., 2017). These capabilities help a person avoid distractions and communicate appropriately. Additionally, one can restrain anger and frustration. When individuals can control their feelings and thoughts, their behaviour will be expressed in the right and proper way.

Cognitive Flexibility (CF) is a broad term that generally refers to our ability to easily adapt to our constantly changing environment and situations (Center on the Developing Child at Harvard University, 2011; Hendry et al., 2016; Phillips-Silver & Daza, 2018) and update our strategies when the need for change has become sufficiently salient (Howard & Melhuish, 2017). When there is more than one topic to think about, children need to use this ability to solve problems, find new ways to solve them, and evaluate the relationships between different concepts (The Understood Team, 2021). They can let go of their old ways of doing things in order to use new ones. Moreover, it should enable them to change their points of view and switch from one task to another (Chutabhakdikul et al., 2017). Additionally, children should be able to adapt time, manner, and target to fit new situations.

Various methods were used to assess executive functions for behavioral performance levels. A suitable method of assessment is to observe preschool children's behavior. Isquith et al. (2005) designed the Behavioral Rating Inventory of Executive Function – Preschool (BRIEF-P). This brief assessment method was designed to measure the behavior of children aged between 2–5 years old. The assessment was done by teachers and parents and involved asking 63 questions. Using questionnaires, the teachers and parents had to observe the child's behavior then rate the frequency using 1 = never, 2 = sometimes, and 3 = often. The questions were used to assess 5 executive function behaviors in children experiencing difficulties, namely inhibition, shifting, emotional control, working memory, and planning/organizing. Chaiakaraphong (2020) assessed a child's performance using a simulation where the situation was not real, but the child's behavior was revealed nonetheless. In this assessment, the handbook, criteria, and score were all analytic rubrics. Furthermore, in Thailand, the MU EF-101 (Mahidol University Executive Function Test) was used to assess EF development, whereas the MU EF-102 (Mahidol University Executive Function Test) was used to assess behavior problems (Chutabhakdikul et al., 2017). To assess each child's EF behavior using this method, the observers must be close to and familiar with the child.

Conceptual Framework of the Study

Based on the comprehensive literature review related to executive function behavioural of preschool children at 3–4 years old, the study's conceptual framework was created (Figure 1).

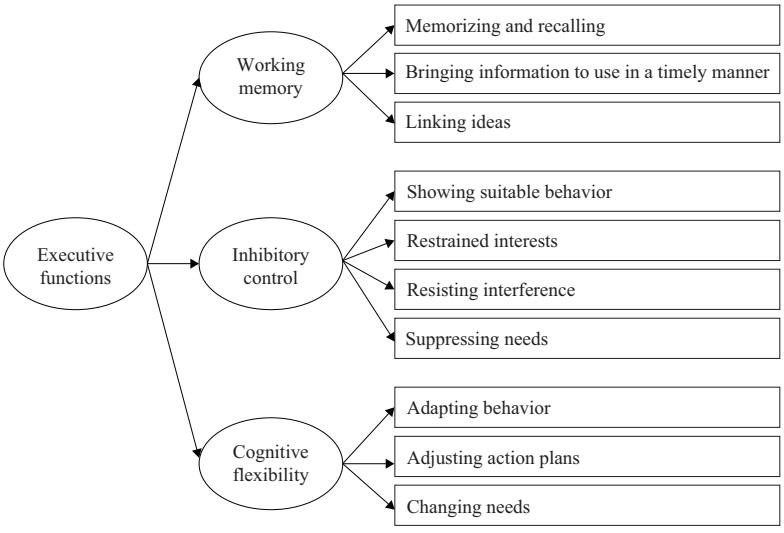

Figure 1 The components and indicators of executive functions

Methodology

This study utilized a survey method. The researchers began by studying and synthesizing components, behavioural indicators, and evaluating executive functions in preschool children aged 3–4 years old.

Participants

The research population consisted of preschool students aged 3–4 years old. The sample comprised 389 students from schools under the jurisdiction of the Office of the Basic Education Commission, local administrative organizations, and the Office of the Private Education Commission with preschool levels in 6 regions of Thailand. The sample was obtained through multi-stage random sampling, with the following steps: (1) cluster sampling from the list of provinces in each region: North: Chiang Rai, Mae Hong Son, and Lampang provinces, Central: Phra Nakhon Si Ayutthaya, Saraburi, and Lopburi provinces, East: Sa Kaeo, Rayong, and Chonburi provinces, West: Tak, Phetchaburi, and Ratchaburi provinces, Northeast: Kalasin, Sakon Nakhon, and Ubon Ratchathani provinces, and South: Phatthalung, Trang, and Nakhon Si Thammarat provinces; (2) cluster sampling from schools in 3 affiliations of each region: Schools under the Office of the Basic Education Commission: Chiang Rai, Ayutthaya, Sa Kaeo, Tak, Kalasin, and Phatthalung, Schools under local administrative organizations: Mae Hong Son, Saraburi, Rayong, Phetchaburi, Sakon Nakhon, and Trang, and Schools under the Office of the Private Education Commission: Lampang, Lopburi, Chonburi, Ratchaburi, Ubon Ratchathani, and Nakhon Si Thammarat; (3) cluster sampling from schools in each province, resulting in 18 schools; and (4) cluster sampling from Kindergarten 1 classrooms, resulting in 389 Kindergarten 1 students from one classroom per school. This sample size aligns with Soper (2023) guidelines for determining sample sizes in structural equation modeling (SEM) studies. Specifically, Soper (2023) recommends a minimum sample size of 156 as a general rule of thumb for SEM analyses.

Data Collection

Data were collected from 10 essay questions to assess preschoolers' executive functions (EFs). Modified EF indicators from the Center on the Developing Child at Harvard University (2011), Hendry et al. (2016), Howard and Melhuish (2017), Phillips-Silver and Daza (2018), Palittapongarnpim (2018), The Understood Team, (2021) and Wiebe et al. (2011) provided three components and ten indicators as synthesis. Experts evaluated linked hypotheses by compiling components and ten indicators of executive functions into questionnaires. The index of conformance (IOC: Index of Item Objective Congruence), which provides a way to verify structural validity, was used to ensure that the material was consistent or that each component was in the same direction. In addition, it ensured the consistency of each component's indicators. The researcher chose the scorecards from 3 experts which had an IOC value larger than 0.60.

The assessment of executive functions in children aged 3–4 years old was conducted using scores from analytic rubrics. Eighteen classroom teachers observed the EF behaviours of their own students and recorded the results in an EF assessment form. They used analytic rubric scoring criteria and rated behaviours on a 4-level scale: 3, 2, 1, and 0. Before using this assessment form, teachers were given detailed instructions on its proper use.

Data Analysis

Confirmatory Factor Analysis (CFA) was used to analyse the data using the LISREL Version 9.30 program. Its estimated parameters were calculated from the Maximum Likelihood (ML) to investigate the structural linearity. In addition, the congruence of the model was based on the empirical and theoretical structural equations by considering the statistical measure of the level of conformity. Chi-square, chi-square/*df*, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Comparative Fit Index (CFI), Standard Root Mean Square Residual (SRMR), Root Mean Square Error of Approximation (RMSEA) and comparisons of the importance of the components and of the empirical data were all used to determine the factor loading.

Results

The objective was to develop Executive Function indicators of preschool children in Thailand. The results show that the Executive Functions are composed of 3 components and 10 indicators. The Executive Function assessment form was validated by 3 experts who used the Index of Objective Congruence (IOC) ranging from 0.33–1.00. The suitable behavioural indicator of inhibitory control was 0.33. In summary, there are 9 indicators. The first component is working memory. It is composed of 3 indicators: memorizing and recalling,

bringing information to use in a manner, and linking ideas. The second component is inhibitory control which has 3 indicators: restraining interests, suppressing needs, and resisting interference. The third component is cognitive flexibility. It is composed of 3 indicators, which are adjusting action plans, changing needs, and adapting behaviour.

A second-order Confirmatory Factor Analysis (CFA) of Executive Functions was also conducted and it showed that the overall fit of the model with the data was good (χ^2 = 27.95, *df* = 21, *p* = .14, χ^2 /*df* = 1.33, RMSEA = .03, GFI = .98, AGFI = .97, SRMR = .02). Cognitive flexibility had the highest factor loading (.98), followed by working memory and inhibitory control (.86). Variable factor loading ranged from .57 to .66, and the discrepancy ratio was expressed as a percentage of variables ranging from 72 to 96. The results are shown in Table 1 and Figure 2. The Confirmatory Factor Analysis of the Executive Functions of the 389 preschool children suggested that all of the indicators met the criteria. These results confirmed that the model was consistent with the empirical data.

Table 1 The validity analysis of the conceptual elements of executive functions in preschool children

Variables	Loading	Standard Error	t	R2
Working memory	0.86	0.05	17.57	0.74
WM1	0.66	0.03	22.45	0.81
WM2	0.63	0.03	22.23	0.80
WM3	0.62	0.03	21.69	0.77
Inhibitory control	0.86	0.05	16.71	0.73
IC1	0.58	0.03	20.96	0.75
IC2	0.57	0.03	20.33	0.72
IC3	0.57	0.03	21.68	0.78
Cognitive flexibility	0.98	0.05	19.24	0.96
CF1	0.62	0.03	20.32	0.74
CF2	0.57	0.03	20.03	0.73
CF3	0.58	0.03	20.09	0.72

Note: WM1 = Memorizing and recalling, WM2 = Bringing information to use in a timely manner, WM3 = Linking ideas, IC1 = Restraining interests, IC2 = Suppressing needs, IC3 = Resisting interference, CF1 = Adjusting action plans, CF2 = Changing needs, CF3 = Adapting behavior, WM = Working Memory, IC = Inhibitory Control, CF = Cognitive Flexibility

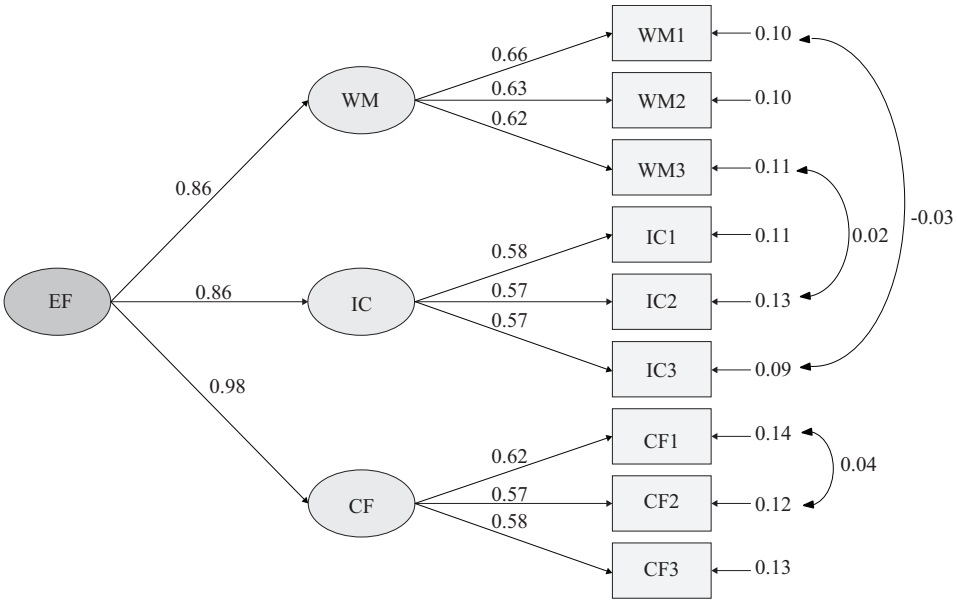

Figure 2 A second order confirmatory factor analysis of the executive functions in preschool children at 3–4 years in Thailand
Note: Chi-Square = 27.95, *df* = 21, *p* value = .14, RMSEA = 0.03

Discussion

The research aimed to develop the indicators of EFs in preschool children aged 3–4 years old. To study the basic data about the components, indicators, and the EF assessment of preschool children aged 3–4 years old, the researchers reviewed the concepts, theories, and related research. We discovered that the components and EF indicators of preschool children consisted of 3 components (Howard & Melhuish, 2017). They are working memory, inhibitory control, and cognitive flexibility. These are the main EF components and the foundation leading to a more advanced level. The mentioned components related to this research are part of a conceptual framework that includes the concepts, theories, and other studies about statistical factors. Indeed, the 3 EF components were tremendously important. The construct validity was evaluated by a second-order CFA. As a result, the highest loading factor was cognitive flexibility. The EFs in preschool children first begin to develop with their cognitive flexibility, when the children are activated and supported. Chevalier and Blaye (2008) mentioned that a lack of cognitive flexibility in some preschoolers was affected by poor activation.

The results showed that all EF indicators were significantly related to each other. The most correlated pair was "Adjusting action plans" and "Changing needs". The most essential aspect of cognitive flexibility was to adjust, adapt, and change. It is a goal-oriented behavior to accomplish tasks. When children discover other solutions, they tend to choose new ways and change their needs. When they struggle to accomplish a task, they use their working memory. The chosen memories are short-term memories as well as activated long-term memories. These memories are then used immediately by linking the ideas together, combining old and new experiences, and adapting by adjusting to the concept and environment in order to continue the activity or task. Even though interesting things or obstacles can be encountered, children are able to suppress their interests and behave appropriately.

The total average for the working memory indicators was the highest, as a 3-year-old child has the ability to memorize rules (Center on the Developing Child at Harvard University, 2011). The "remembering and recalling" indicator had the highest total average score among working memory and EF indicators, and thus was the most powerful predictor of higher-level cognition (McCabe et al., 2010).

The results of the second-order confirmatory factor analysis for all the topics revealed that the factor loading was between .86 to .98 and was statistically significant at the .05 level. When ranking the indicators that are suitable as indicators of EFs, the results showed cognitive flexibility with a loading factor of .98, and working memory and inhibitory control with loading factors of .86. The data show that the EF indicators for preschool children are cognitive flexibility, working memory, and inhibitory control.

To develop tools for EF assessments in preschool children, the scoring criteria should be set using analytical scoring rubrics. The rubric properties should be qualified using clear criteria and comparative language to differentiate quality (Wiggins, 1998). The developed assessment questionnaire's quality was high, with a coefficient alpha > 0.9 (Kanchanawasri, 2012).

Conclusion and Recommendation

The study concluded that the indicators of executive functions in preschool children aged 3–4 years old in Thailand consisted of 3 components and 9 indicators. The research findings showed that the second-order Confirmatory Factor Analysis of the Executive Function model was consistent with the empirical data. This provided clear evidence that there are 3 main components supporting executive functions. These components include working memory, inhibitory control, and cognitive flexibility. The results of this research will help teachers, educators, and those involved with preschool children to use this EF assessment tool to observe the behaviour of children under their care, providing information for behaviour modification and further behavioural support.

Conflict of interest

The authors declares that there is no conflict of interest.

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