

## Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
<b>TITLE</b>			
Title	1	The executive function skills of students in higher education: a scoping review	1
<b>ABSTRACT</b>			
Structured summary	2	This scoping review aimed to comprehend and synthesise the evidence regarding higher education students' executive function skills. JBI guidelines were followed in conducting a scoping review of the literature. Databases searched included EBSCOHost, Web of Science, and Scopus. Twenty-five articles published between 2013 and 2023 were included. Factors contributing to or affecting students' academic achievement because of lower executive function abilities were identified. Executive function skills hugely contribute to ensuring optimal academic achievement in higher education. Suggestions for improving executive functions are offered. Executive functions are the cognitive abilities that enable individuals to intentionally control their actions. In a higher education setting, executive function skills are required to enhance students' academic achievement. This type of information has significant potential to inform higher education practices to better understand the gaps and impacting factors on higher education students' academic achievement. The reviewed data, alert researchers to possibilities for enhancing executive function skills by employing a holistic approach resulting in academic achievement.	1
<b>INTRODUCTION</b>			
Rationale	3	<p><b>Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.</b></p> <p>University students' poor academic performance is associated with decreased efficiency in their EF. EFs play a vital role in the processing of information and knowledge, but they also play a critical role in regulating behaviour to achieve long-term objectives, which are essential components in determining whether to pursue further education or end academic studies. Exploring the literature of significance could prove to be beneficial to enhance EF within HE students resulting in academic achievement.</p> <p>Scoping reviews are used to provide a comprehensive overview of the evidence on a topic, regardless of</p>	3-4

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		research quality, and are valuable for analysing developing topics, clarifying essential concepts, and identifying gaps. A scoping review is conducted based on the existing literature, which aims to map the current literature and provide a comprehensive summary of the extensive and varied literature associated with the EF skills of students in HE settings. Therefore, a scoping review fits the purpose of this study.	
Objectives	4	<p><b>Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.</b></p> <p>What is known from the existing literature about the EF skills of students in higher education settings?</p> <p>The participant, concept, context (PCC) method are employed for this scoping review. The eligibility criteria excludes participants in preschools, primary schools and high schools since the focus is on HE students. Participants are not excluded based on their geographical background, gender, or race. The concept under investigation is the EF skills of students in a HE context. No eligibility criteria are specified relating to a specific educational field.</p>	5
<b>METHODS</b>			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	<a href="#">Click here to enter text.</a>
Eligibility criteria	6	<p><b>Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.</b></p> <p>Inclusion criteria:</p> <ul style="list-style-type: none"> <li>• Research published in 2013-2023</li> <li>• Articles published in peer-reviewed journals</li> <li>• Focus on students in higher education</li> <li>• Any research design</li> <li>• Population of undergraduate students enrolled at a higher education institution</li> </ul> <p>Exclusion criteria:</p> <ul style="list-style-type: none"> <li>• Other languages besides English</li> <li>• The population of children in preschool, primary school or adolescents in high school</li> <li>• Health-related studies</li> <li>• Grey literature, reports, discussion pieces, reviews, opinions, and conference proceedings</li> </ul>	5-6

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Information sources*	7	<p><b>Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.</b></p> <p>The following databases were accessed: Taylor and Francis, EBSCOhost, Web of Science, and Scopus. In the end, Taylor and Francis were removed as an option due to irrelevant articles and duplicates. Searching commenced during November 2023. The most recent search was executed on 2023-12-10.</p>	n/a
Search	8	<p><b>Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.</b></p> <p>Boolean operators were identified to capture studies associated with the EF skills of undergraduate students in HE. The search strategy (Boolean operators), are adjusted for each included database. A full search strategy are developed for EBSCOHost, Web of Science, and Scopus.</p> <p>("executive function*" or "executive function* skills" or "working memory" or "cognitive flexibility" or "inhibitory control") AND ("higher education" or "tertiary education" or university or college) AND ( student or "student teach*" or "preservice teach*" or "pre-service teach*" or practicum) AND ("academic achiev*" or "academic performance" or "academic success" or "education* success" or "student success" or "student achiev*") NOT ("primary school" OR "elementary school" OR kindergarten OR "primary education" OR "elementary education" OR preschool OR "pre-primary school" OR "secondary school" or "middle school" or adolescent* or teenager* or child* OR childhood OR learner*) NOT (disab* OR impair* OR special OR "special needs" OR disorder OR disease OR patient* or health)</p>	6
Selection of sources of evidence†	9	<p><b>State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.</b></p> <p>Following the predetermined search, articles are identified and uploaded into the citation software, Zotero, version 6.0.30 (2023) and duplicates are</p>	5-6

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		removed before being imported into Rayyan, which is a software used to conduct systematic reviews.	
Data charting process‡	10	<p><b>Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.</b></p> <p>Two independent reviewers extracted data from the identified studies using a Microsoft Excel extraction spreadsheet. During this entire process, the data extraction tool underwent several modifications. Modifications included additional information added to the extraction spreadsheet relating to HE students' EF skills. One reviewer extracted data from the eligible publications; an additional reviewer verified the reliability and validity of the information collected. Any disputes that developed amongst the reviewers are addressed through discussion. A copy of the Excel data extraction instrument with modifications made throughout the review are attached.</p>	5-6
Data items	11	<p><b>List and define all variables for which data were sought and any assumptions and simplifications made.</b></p> <p><i>Executive function (EF)</i> EF, also known as cognitive control (Diamond, 2013), is defined as the abilities that enable individuals to set and accomplish goals while disregarding feelings, actions, or ideas that could get in the way of reaching an objective (Romero-López et al., 2021), especially in daily challenging situations (Davidson et al., 2006; Friedman &amp; Miyake, 2017).</p> <p><i>Cognitive flexibility (CF)</i> According to Dennis and Vander Wal (2010), CF involves three facets: (1) the inclination to view challenging circumstances as within one's control; (2) the capacity to consider various alternative interpretations for life events and human actions; and (3) the skill to develop numerous alternative resolutions for challenging scenarios.</p> <p><i>Working memory (WM)</i> WM allows for the temporary storage of data in memory for future processing (Gray-Burrows et al., 2019), while adding useful data or eliminating unnecessary information to accomplish a goal (Miyake et al., 2000).</p>	3-4

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		<i>Inhibitory control (IC)</i> Diamond (2013) asserts that the presence of IC empowers individuals to modify and determine their responses and actions instead of adhering to established habits.	
Critical appraisal of individual sources of evidence§	12	Not required for scoping reviews.	n/a
Synthesis of results	13	<b>Describe the methods of handling and summarizing the data that were charted.</b>  A descriptive qualitative content analysis method is used to narratively synthesise textual information regarding the rationale behind the existing evidence of EF in the HE setting. The synthesised data comprise descriptions of the various factors affecting students' academic achievement in HE. Tables, figures, and narrative descriptions of results applicable to the review's objectives and questions are used to present the data.	7
<b>RESULTS</b>			
Selection of sources of evidence	14	<b>Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.</b>  Three electronic databases are searched for peer-reviewed published literature resulting in 8234 articles. The abstract and title of 1042 articles are screened after 7192 irrelevant articles are excluded. 55 full-text and peer-reviewed articles are retrieved and screened by two independent reviewers. Following the removal of irrelevant articles, the two independent reviewers extracted 55 full-text articles and screened them, yielding 37 articles that complied with the qualifying criteria. At the end of the screening process, a total of 25 full-text articles remained. Many of the records that emerged did not relate to the topic of the study. The study's target population, unavailability of full-text articles, articles published outside the specified range, and EFs based on health-related studies were common reasons for exclusion. The Prisma-ScR flow diagram is completed and included on page 7.	7
Characteristics of sources of evidence	15	<b>For each source of evidence, present characteristics for which data were charted and provide the citations.</b>  A table is developed to display the characteristics of each source of evidence.	p. 8-12

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Critical appraisal within sources of evidence	16	Not required for scoping reviews.	n/a
Results of individual sources of evidence	17	<p><b>For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.</b></p> <p>Detailed information is available on the attached excel spreadsheet for each included source of evidence.</p>	attached
Synthesis of results	18	<p><b>Summarize and/or present the charting results as they relate to the review questions and objectives.</b></p> <p><i>Methodologies</i> The majority of articles n=21 (84%) employed a quantitative research design. EF can be evaluated using a range of methodologies. The main ones used are laboratory assessments (computerised cognitive training) and behavioural rating scales. Students' Grade Point Average (GPA) is usually used to evaluate academic performance.</p> <p><i>Publication year</i> Thirteen out of the twenty-five studies were conducted between 2021 and 2023. This implies that the studies offer insights into current trends and developments in education.</p> <p><i>Sample size</i> The total number of students involved in the included research articles falls within the range of 101 to 300.</p> <p><i>Interdisciplinary focus</i> The investigations include a wide range of disciplines: education, psychology, engineering, teacher education, culinary arts, educational psychology, and students pursuing careers in pedagogy.</p> <p><i>Countries of origin</i> The studies were conducted with HE students in 12 different countries: USA, Turkey, Ecuador, Canada, Singapore, Taiwan, Morocco, Pakistan, Ireland, Brazil, Israel, and Switzerland.</p> <p><i>Limitations</i> Various limitations are reported: sample demographics, methodological constraints, potential biases, and representativeness of the sample.</p> <p><i>Addressing executive function challenges in HE</i> Flipped classrooms or the enhancement of instructional design promote student performance. Other research indicates that the implementation of intervention programmes promotes students' EF.</p>	13-14

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<b>DISCUSSION</b>			
Summary of evidence	19	<p><b>Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.</b></p> <p>The following themes emerged:  Executive functions and academic achievement  <i>Other factors playing a role in student's EF skills development</i></p> <ul style="list-style-type: none"> <li>• Importance of teacher perceptions and training in student-teacher interactions and academic achievement</li> <li>• Technology</li> <li>• Motivation</li> <li>• Gender differences; fluid intelligence and academic achievement</li> <li>• Factors affecting EF</li> </ul>	15-18
Limitations	20	A few omissions might occur due to the search criteria used. The topic-keyword combinations that are selected might cause other relevant research to be overlooked.	19
Conclusions	21	<ul style="list-style-type: none"> <li>• Review 25 research articles.</li> <li>• Studying EFs in HE is crucial since each of these functions must be functioning at the proper level for the students to succeed in their studies.</li> <li>• Implement computerised cognitive training programmes for short-term enhancement of EFs. However, a holistic approach to enhance EF is preferred.</li> <li>• Variety of measuring instruments are used, which makes it difficult to summarise the content.</li> <li>• A lack of development in various EF-related skills (flexibility, time management, behaviour control, etc.) causes EF deficits, resulting in academic failure.</li> <li>• HE institutions should plan intervention strategies to enhance students' chances of academic success.</li> </ul>	18-19
<b>FUNDING</b>			
Funding	22	No financial support is provided for this article.	20

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

\* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 16 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

*From:* Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA ScR): Checklist and Explanation. *Ann Intern Med.* 2018;169:467–473. doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850).