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Empowering Minds: Harnessing the Potential of Cognitive Field Independence and Dependence in STEM Education

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Abstract
The purpose of this article is to discuss the importance of cognitive field independence and field dependency in STEM (Science, Technology, Engineering, and Mathematics) education. It discusses the critical topic of cognitive types and their impact on STEM learning and problem-solving. This study intends to illuminate how educators might harness these cognitive features to empower students in their STEM learning journeys by investigating the characteristics and benefits of field independence and reliance. The study focuses on the success of field-independent learners in analytical and abstract thinking, as opposed to field-dependent learners' ability for holistic and context-based comprehension. It also looks into methodologies and pedagogical approaches for accommodating diverse cognitive styles in order to create inclusive and engaging learning environments. Recognizing and cultivating the qualities of field independence and dependency can help educators unlock students' full potential and foster a diverse range of problem-solving skills in the STEM industry. Finally, this paper emphasizes the necessity of recognizing cognitive variety and harnessing it as a significant tool for increasing creativity and achievement in STEM education.
Keywords: STEM, Cognitive, Field Independent, Field Dependent

Introduction

Cognitive processes, which include perception, attention, memory, and problem-solving, have a considerable impact on how people perceive, process, and retain information (Riding & Rayner, 1998). A thorough knowledge of how these cognitive characteristics interact with learning styles and motivation is critical for establishing successful educational interventions that promote academic achievement and STEM engagement (Idris et al., 2023c).

Idris et al (2023a) conducted a recent study that throws light on the issues and obstacles faced by STEM education in Malaysia in terms of student enrolment in STEM courses at schools. This study emphasises the critical necessity to address these difficulties and emphasises the importance of investigating cognitive aspects in order to create appropriate solutions.
Numerous research have been undertaken to investigate the relationship between cognition and learning styles, indicating individual variances in information processing that influence learners' knowledge acquisition and assimilation (Chen et al., 2019a). Learners' approaches to tasks and information organisation are shaped by cognitive styles such as field dependence/independence or holistic/analytic thinking (Witkin et al., 1977).
Furthermore, people with a holistic cognitive style like to look at the overall picture, whereas those with an analytic approach want to break information down into smaller pieces. These cognitive styles have significant implications for instructional tactics and learning material design to coincide with learners' cognitive preferences (Sadler-Smith & Riding, 1999: Chen et al., 2019b).

Group Embedded Figure Test (GEFT)

Witkin et al (1977) proposed a cognitive theory targeted at recognising individual pupils' cognitive tendencies in school learning. They believed that cognitive levels begin to develop in children at an early age. Herman Witkin and his colleagues' cognitive theory has been widely employed in social science research and educational studies (Sozcu, 2014). Based on the proposed framework by Kurt Gottschaldt, a German psychologist, and the psychological influence from Gestalt theory, Witkin et al. (1997) developed the Embedded Figure Test (EFT) as a group test to assess cognitive and analytical abilities in the field-independent or field-dependent dimensions.
Individuals are classified as field-independent or field-dependent based on the Group Embedded Figure Test (GEFT) results. The preference for field independence or field dependence may not always suggest a good or bad thing, but it may be more advantageous in specific instances (Evans et al., 2013). It can, for example, assist in identifying appropriate job pathways depending on an individual's cognitive abilities. Individuals with a field-independent tendency tend to excel in fields such as mathematics, engineering, carpentry, and agriculture, whereas those with a field-dependent tendency likely to excel in fields such as social work, advertising, and sales (Witkin et al., 1977).
Furthermore, Rezeki et al (2020) indicated that students with field-independent cognitive styles excelled guided inquiry learning procedures when taught utilising an inquiry-based learning approach suited to individual students. Witkin's cognitive theory supports this, claiming that field-independent individuals focus on their particular abilities without the need for instruction or observation from teachers or others.
Aside from that, Tascon et al (2017) feel that students with field-independent and field-dependent cognitive styles benefit in different ways from diverse learning environment designs, notably in STEM education, which incorporates a variety of learning methodologies across disciplines. Liu (2018) discovered that by using different information formats during learning, students with field-independent cognitive styles could describe visual signals more effectively in the classroom.
Following that, Chen et al (2019b) discovered that people with a field-dependent cognitive style rely on external references or environmental cues while processing acquired learning material, whereas people with a field-independent cognitive style process information using internal perceptual cues. Students with a field-dependent cognitive style, according to Ho et

al (2017), benefit more from technology-enhanced learning environments than students with other cognitive types. This is because graphic features and visual instruction help field-dependent students excel in technology-enhanced learning environments.
This cognitive theory is also a variable that determines academic and vocational choices, academic development, student learning styles, and teacher-student interactions in schools (Demick, 2014). The cognitive theory includes 18 questions based on a geometry recognition test that evaluate cognitive inclinations. Two sub-dimensions of cognition are identified from these 18 questions, represented by field-independent or field-dependent persons (Witkin et al., 1977).

Table 1
Group Embedded Figure Test (GEFT)

Field Independent	**Field Dependent**
Students can easily rearrange information to perform the process of separating geometric shapes.	Students face difficulties in performing the process of separating given geometric shapes.
Students are less influenced by social reinforcement in learning.	Students are unable to overcome the main distractors that hinder their focus during learning.
Students understand the learning environment analytically.	Students have a global and passive nature.
They possess strong reasoning skills.	Students possess moderate reasoning skills.
Students prefer self-learning over learning with others in groups.	Students tend to work and learn in groups.
They excel in problem-based learning that requires students to grasp the overall context of the learning material.	Students excel in social activities and learning at school.
They have an individualistic attitude and approach to learning.	Students have a collective and cooperative attitude and approach to learning in groups.
They are not easily influenced by criticism from others.	Students are easily influenced by the criticism given.
They are capable of analyze and organizing the situations encountered during learning.	They are capable of seeing the learning situation globally but are unable to organize it.
Students enjoy solving problems in learning without guidance from teachers or other students	Students require guidance and direction from teachers to solve problems during learning.

They accept ideas that are reinforced through analysis.	Students accept open ideas presented to them.

GEFT on STEM Education

Students with field independent cognition outperformed those with field dependent cognition in terms of learning achievement and academic performance (Sujito et al., 2019). Field independent students were more interested in STEM disciplines, with 60% of individuals changing their career inclinations to STEM sectors after participating in STEM-related activities (Donmez, 2021). According to Rezayat and Sheu (2020), extracurricular activities can have a greater beneficial impact on STEM motivation than studying science classes. By getting relevant expertise in science subjects, you can help develop interest in STEM.

Field independent and field dependent knowledge dimensions were diverse. According to Lin et al (2018), collaborative problem-solving activities in learning increased the learning outcomes of students with varied cognitive styles. Students who were field reliant had an additional high-level knowledge dimension (evaluate) as well as various transfers of knowledge deepening and cognitive process patterns. Through the learning process, they were able to apply, analyze, and even reflect on previously acquired knowledge.

The impact of cognitive styles on learning outcomes in STEM education was investigated in these research. According to Lu and Lin (2018), students with a field-independent cognitive style were less engaged in collaborative learning activities than their field-dependent counterparts. This implies that pupils with a field-independent cognitive style approach tasks more independently and rationally.

Students with a field-dependent cognitive style, on the other hand, displayed a greater level of knowledge dimension in evaluation, showing their capacity to appraise material more successfully (Peng et al., 2018). Donmez (2021) focused on job choice changes among female STEM students, taking into account different cognitive types. The findings showed that participating in STEM activities outside of school influenced students' cognitive ability in STEM. Students with a field-independent cognitive style were more likely to switch careers to STEM professions, highlighting the importance of extracurricular STEM activities in moulding career selections.

Setiawan et al (2020) further highlighted the influence of cognitive styles on problem-solving abilities and mathematical reasoning. Students with a field-independent cognitive style outperformed those with a field-dependent cognitive style in terms of reasoning and problem-solving abilities, particularly in geometric areas. Chen et al (2019) investigated the Flipped Classroom setting and discovered substantial variations in cognitive styles, with field-independent students outperforming their peers academically. These findings highlight the necessity of taking cognitive types into account in STEM education and modifying teaching tactics to improve learning outcomes and engagement.

Overall, these studies highlight the importance of considering students' cognitive styles in STEM education. Understanding the cognitive characteristics of students can assist educators in tailoring teaching strategies and interventions to enhance learning outcomes and engagement in STEM subjects. Based on figure 1, the researchers proposed a theoretical framework for the study of cognitive relationships to STEM education and further implications for career tendencies in STEM fields in schools.

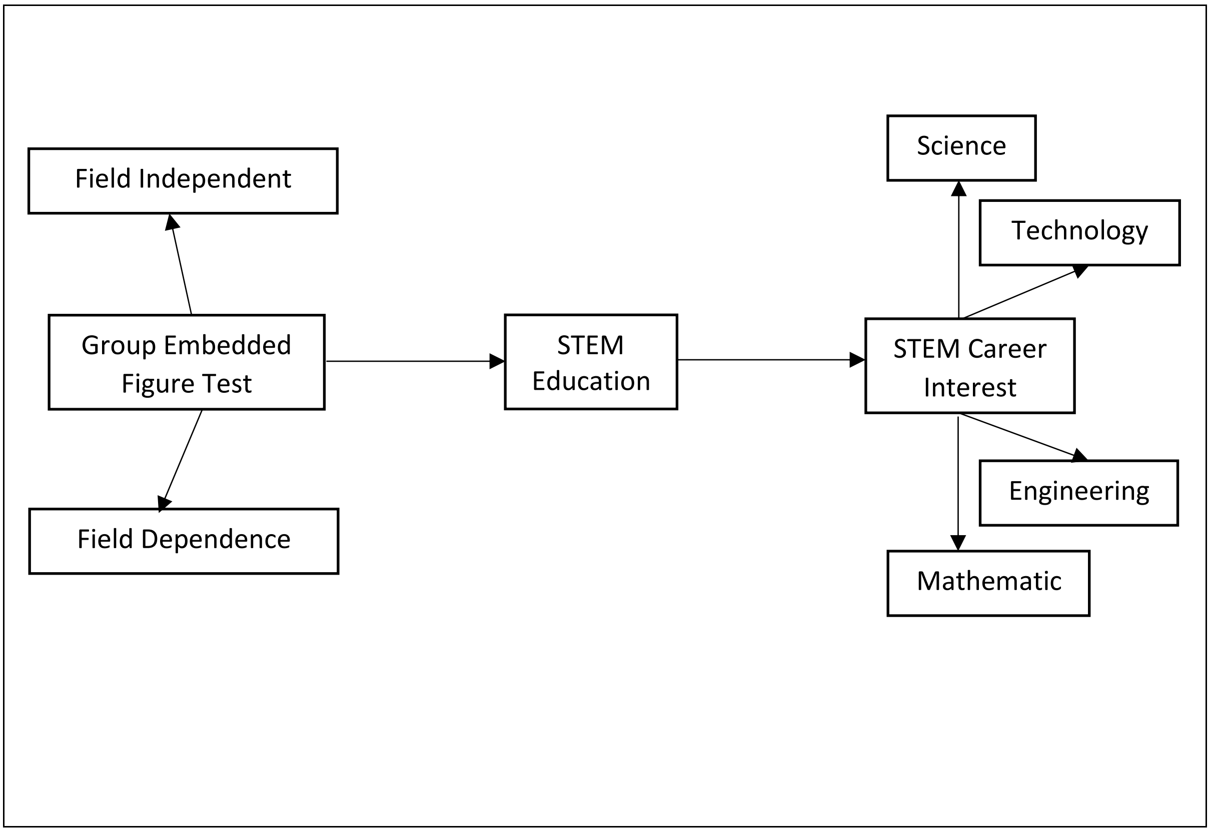

Figure 1. Theoritical Framework Proposed by Researcher

Discussion

STEM (science, technology, engineering, and mathematics) education is becoming increasingly important for encouraging innovation, economic growth, and global competitiveness (Idris & Bacotang, 2023). However, the success of STEM education goes beyond topic knowledge because cognitive characteristics play a significant role in influencing students' achievement and interest in STEM disciplines. Problem-solving, creativity, and metacognition are critical for success in STEM subjects (National Academy of Engineering, 2014).

According to research, students with stronger cognitive abilities are more likely to prosper in STEM schooling and seek professions in STEM subjects. Cognitive talents such as spatial reasoning, problem-solving, and analytical thinking are strongly associated with STEM involvement and achievement (Dutta et al., 2015; Wang et al., 2016). Understanding and harnessing cognitive variables is therefore crucial for increasing interest and success in STEM education (Donmez, 2021).

The use of learning style and cognitive characteristic identification into a learning management system has the potential to be revolutionary. This integration allows for personalised instruction, tailored resources, and adaptive learning experiences, allowing learners to embark on a path of self-discovery and educational advancement (Lwande et al., 2021). Furthermore, STEM-based education has showed promise in improving elementary school children's cognitive capacities (Firdaus & Rahayu, 2019).

The cognitive movement in education emphasises the significant impact that cognitive processes and metacognitive methods have on learning outcomes. Innovative instructional approaches based on cognitive science can improve educational outcomes by encouraging higher-order thinking, self-regulation, and lifelong intellectual progress (Di Vesta, 1987).

Students that have well-developed cognitive talents that are appropriate for STEM education have a distinct advantage in analytical thinking, problem-solving, and critical reasoning. These cognitive abilities promote exploration, discovery, and achievement in the fast-paced world of STEM disciplines (Zeng et al., 2018). Teachers' and parents' support is also important in moulding pupils' positive attitudes towards future STEM education and career options (Rivera & Li, 2020).

Integrating cognitive science ideas and advanced technologies in the STEM classroom creates a revolutionary learning environment. This combination improves instructional tactics, increases student engagement, and promotes a deeper conceptual comprehension of complicated scientific subjects (Butler et al., 2014). Furthermore, the cognitive apprenticeship framework has been shown to be successful in developing the cognitive abilities and knowledge necessary for success in STEM graduate study (Minshew et al., 2021).

STEM education has the ability to stimulate brain activity, foster curiosity, and build critical thinking skills in preschool-age children. Early STEM education lays the groundwork for a lifetime of interest and participation in science, technology, engineering, and mathematics (Ros et al., 2016; Qureshi & Qureshi 2021).

Providing fair access to resources and creating inclusive environments are critical for empowering primary and preschool students in STEM education. To develop interest in STEM areas, it is critical to solve problems and provide engaging and equitable learning experiences (Shifrer & Freeman, 2021). Embodied cognition improves students' grasp of abstract topics and encourages holistic problem-solving approaches in STEM (Weisberg & Newcombe, 2017).

Long-term interventions in integrated STEM education can improve students' cognitive function. They improve students' problem-solving abilities, critical thinking skills, and interdisciplinary knowledge, equipping them for success in the twenty-first century (De Loof et al., 2022). Participation in STEM projects and summer camps enhances the likelihood of students majoring in STEM in college (Sahin et al., 2017).

Educators and researchers may build effective instructional strategies, personalised learning experiences, and supportive settings that empower students in STEM education and professions by recognising and utilising the importance of cognitive factors. Understanding the relationship between cognition and STEM education opens the door to innovation and excellence in these critical domains of study.

Conclusion and Future Agenda

To summarise, the influence of cognitive field independence and reliance in STEM education is considerable and provides a plethora of options for mind empowerment. Field independence and field dependency are unique cognitive processes that influence learning, problem-solving, and general engagement in STEM fields. Educators can build inclusive teaching strategies that cater to the different requirements of students by recognising and appreciating the strengths of each cognitive style.

Analytical thinking, abstract reasoning, and independent problem-solving ability are demonstrated by field-independent learners. They flourish in environments that value individual discovery and foster critical thinking. Field-dependent learners, on the other hand, thrive at holistic comprehension, context-based learning, and collaborative problem-solving. Group activities, hands-on experiences, and interactive learning approaches enhance them.

Future research should concentrate on many critical areas in order to fully realise the promise of cognitive field independence and dependency in STEM education. To begin, future research should focus on successful instructional methodologies and pedagogical approaches that support both cognitive modes at the same time. To meet the varying requirements of students, strategies such as blended learning, adaptive learning technologies, and differentiated education might be considered.

Second, the influence of cognitive field independence and dependency on underrepresented groups in STEM disciplines needs to be investigated. Understanding how different cognitive styles interact with gender, race, and socioeconomic characteristics can aid in the reduction of success inequalities and the promotion of equity in STEM education.

Finally, longitudinal research can shed light on the long-term impacts of cognitive field independence and dependency on career choices and success in STEM disciplines. Investigating how these cognitive patterns affect students' tenacity, motivation, and career satisfaction might help shape educational policy and career advising activities.

Educators may establish inclusive STEM learning environments that empower all students to thrive by embracing cognitive variety and exploiting the possibilities of cognitive field independence and reliance. Recognising and supporting each cognitive style's distinct capabilities can aid in the development of innovative problem solvers, critical thinkers, and future STEM leaders.

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