MIND STRENGTHS: THE UNIQUE COGNITIVE ARCHITECTURE OF ENGINEERING AND TECHNOLOGY STUDENTS

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ABSTRACT

Engineering and technology education is uniquely positioned within formal education systems to facilitate the development of a broad range of cognitive competencies such as designerly thinking, spatial reasoning and modelling. It is posited that this environment requires an entirely different mental discipline due to the substantial presence of design as a learning medium. Therefore, it is paramount to explicitly identify this cognitive architecture to support the educational aims of the discipline.

The 'MIND' strengths framework is presented as a potential cognitive framework for engineering and technology education. Aligning with this, the 'MIND' strengths survey was administered to a cohort of final year engineering and technology education students. The results of this survey identify it as a reliable tool and an initial 'MIND' profile is subsequently deduced. Findings also present the potential of a gender difference favouring males within the survey which aligns with pertinent psychometric literature.

KEYWORDS: Technology and Engineering Education, Cognitive Architectures, 'MIND' Strengths

1. INTRODUCTION

Engineering and technology education is uniquely positioned within formal education systems to facilitate the development of a broad range of cognitive competencies such as designerly thinking, spatial reasoning and modelling. This suite of subjects immerses students in a distinctively dynamic environment mandating the need to operate in an "intermediate zone of activity where hunch, half-knowledge and intuition are essential ingredients" [1]. The embodiment of this environment is design, which Archer [2] identifies as an "entirely different mental discipline". Stemming from this, it is posited that a unique set of cognitive skills is espoused through engagement within this domain.

The postulation that different cognitive capacities are fostered within the subject areas of engineering and technology is pertinent in both post-primary and higher education. Considering this period holistically, pertinent eduction at post-primary level should facilitate students who progress in this field in higher education. However, in contrast to this, there appears to be a negative effect created through engagement with the suite of technology subjects at post-primary level on performance in engineering related disciplines in higher education [3]. This suggests a misalignment within the discipline between levels of education. As the knowledge base expectedly differs between post-primary and higher education, it is theorised that the negative effect stems from a misalignment at a broader cognitive level associated with cognitive faculties rather than a pertinent knowledge base.

The concept of 'MIND' strengths (Material Reasoning, Interconnected Reasoning, Narrative Reasoning and Dynamic Reasoning) was first theorised by [4] as a framework to describe the 'dyslexic advantage', or the unique cognitive strengths that people with dyslexia illustrate. This framework conjointly offers a unique perspective to investigate the potentially unique cognitive architecture of the engineering and technology discipline as they are predicated on the capacity to think visually, and spatial cognition is consistently cited as correlating with performance in this domain [5, 6]. Material reasoning (M-strengths) describes abilities that help people reason about the physical world, Interconnected reasoning (I-strengths) refers to the capacity to identify connections between different objects, concepts, or points of view, Narrative reasoning (N-strengths) allows people to construct a connected series of mental scenes from past episodic experiences, and Dynamic reasoning (D-strengths) indicates the ability to predict past or future states through the utilisation of episodic simulation.

The aim of this study is to initiate an investigation into the potentially different cognitive architecture associated with the technology and engineering discipline within education. Under the hypothesis that different cognitive faculties are nurtured in this domain and adopting the 'MIND' strengths framework as a conceptual framework to guide the investigation, it is envisioned that gathering longitudinal or quasi-longitudinal data could provide significant insight into the cognitive effects on students which occur from engagement in this area. As there is no published dataset providing a quantitative set of results from the 'MIND' strengths survey, this study aims to instigate this investigation through the generation of a 'MIND' strengths profile for students completing higher education in the field of engineering and technology education.

2. METHOD

2.1. Approach and Participants

As the aim of this study was to profile the cognitive architecture of technology and engineering students relative to the 'MIND' strengths framework theorised by Eide and Eide [4], the 'MIND' strengths survey was utilised to elicit students' introspective accounts of their own pertinent cognitive faculties. The survey was administered to a cohort (n=41) of final year undergraduate students studying Materials and Architectural Technology (M&AT) and Materials and Engineering Technology (M&ET). This cohort was selected as it is envisioned that students at this stage of their education would have the most developed cognitive architecture and a higher capacity to introspectively reflect on their cognitive abilities. It was also considered appropriate to initiate this research direction with the deduction of a 'MIND' strengths profile for students at this stage of their education to allow for comparison with students at earlier stages. Full demographic information for the study cohort is shown in Table 1.

Table 1. Participant demographic information

Course	n	Mean Age	Std. Deviation	Male	Female
M&AT	13	21.462	1.713	9	4
M&ET	28	22.857	3.429	24	4

2.2. Design and Implementation

The 'MIND' strengths survey [4] consists of 91 items spanning each of the four categories (M=17, I=26, N=22 and D=26). For each item, participants are presented with a statement describing a specific skill within each of the 4 categories. Participants must then respond on a 5 point Likert-type scale to indicate their introspective agreeance with their ability to carry out the particular cognitive action. For this study the survey was administered electronically to participants and participation was voluntary.

3. FINDINGS

The primary result of this study was the creation of a 'MIND' profile for the participants. This profile is presented in Figure 1. However, as the study cohort was relatively small and due to the non-existence of a comparable dataset, further data analysis needed to be exploratory in nature both to provide insight into the reflective accounts offered by the participants and also to create a dataset for future comparison. Initially, a descriptive analysis was conducted to examine the normality of the data. The results of this are presented in Table 2. The skewness and kurtosis values indicate a sufficient level of normality across each of the categories.

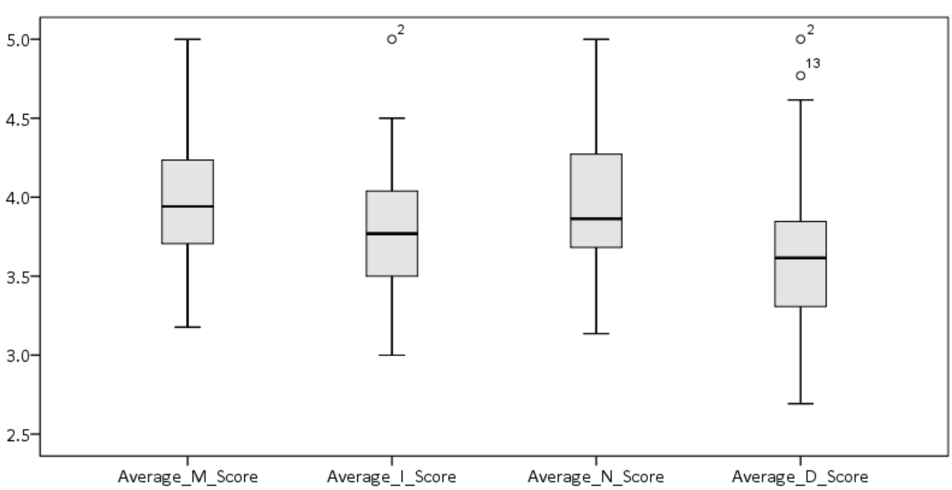

Figure 1. 'MIND' profile for study participants

Table 2: Descriptive statistics of average participant results

Measure	N	Min	Max	Mean	Std. Deviation	Skewness		Kurtosis	
						Statistic	Std. Error	Statistic	Std. Error
M-Strengths	41	3.18	5.00	4.00	.44	.103	.369	-.487	.724
I-Strengths	41	3.00	5.00	3.75	.44	.256	.369	.323	.724
N-Strengths	41	3.14	5.00	3.95	.46	.388	.369	-.070	.724
D-Strengths	41	2.69	5.00	3.67	.50	.673	.369	.522	.724

Subsequent to this, it was deemed necessary to initiate an investigation into the reliability of the tool. Cronbach's Alpha values were generated for each of the four 'MIND' strengths. The Alpha values were 0.821 for material reasoning, 0.861 for interconnected reasoning, 0.839 for narrative reasoning, and 0.887 for dynamic reasoning. These values indicate a high level of internal consistency within each of the factors. A more detailed examination into the factor structure of the 'MIND' strengths framework was beyond the scope of this study as the number of participants was lower than 150, the recommended necessary amount required for a factor analytic approach [7], which prevented the capacity for computational modelling. As this could not be achieved at this stage, a correlation matrix was created between each of the variables (Table 3). Interestingly, despite the small sample size, statistically significant correlations were found between all variables with *p* values ranging from moderate (*r* = .505) to high (*r* = .785). Achieving this result further supports the hypothesis that these variables represent interconnected cognitive faculties which are particular aptitudes of the participants in the study cohort.

Table 3: Correlations matrix for MIND strength scores

	M-Strengths	I-Strengths	N-Strengths	D-Strengths
M-Strengths	1			
I-Strengths	.630*	1		
N-Strengths	.505*	.667*	1	
D-Strengths	.613*	.785*	.523*	1

*. Correlation is significant at the 0.01 level (2-tailed).

Of particular interest at this early stage of this research direction is the identification of any potential gender differences associated with these cognitive faculties. A series of t-tests were conducted to identify any such differences (Table 4). For all 4 categories the mean score for male participants (n=33) was higher than for females (n=8). However, statistical significance was only observed for M-strengths and I-strengths.

Table 4: T-test results for gender differences across each MIND strength category

Measure	Male		Female		*t*	*df*	*p*
	Mean	Std. Deviation	Mean	Std. Deviation			
M-Strengths	4.078	.423	3.677	.398	2.435	39	.020
I-Strengths	3.825	.437	3.428	.335	2.399	39	.021
N-Strengths	3.963	.459	3.875	.477	.482	39	.632
D-Strengths	3.688	.534	3.601	.304	.439	39	.663

In spatial cognition research, a gender difference favouring males is one of the most regularly cited findings [6]. As material reasoning is particularly associated with spatial reasoning, this result is unsurprising. In addition to this, when examining spatial reasoning, Linn and Petersen [8] identify males as preferring a more holistic spatial approach to solving problems with females preferring a more analytical approach. With interconnected reasoning referring to a holistic style of thinking, it may be the case that male and female reasoning styles extend beyond spatial problems and transcend into general problem approaches.

4. DISCUSSION

Despite being a pilot study, many interesting results are offered to guide the conduction of a similar study on a larger scale. Perhaps the most critical consideration associated with the use of this tool is that it is not a direct measure of cognitive capacities but rather an introspective account by the participant. Therefore, the progression of this research necessitates the employment of a tool which can explicitly measure such capacities. For example, the utilisation of psychometric tests associated with each of the 'MIND' strengths, such as those within the Kit of Factor-Referenced Cognitive Tests [9], in conjunction with the 'MIND' survey, would not only provide explicit measures of cognitive skills and introspective accounts, but it would allow for an analysis of students introspective accuracy which is a critical element to the 'MIND' framework.

As previously discussed, there exists no published dataset including quantitative results from the 'MIND' strengths survey. Therefore, the study described in this paper served to determine the reliability of the survey instrument and to gain insight to guide its future use within technology and engineering education. Despite not being able to examine the factor structure of the survey, high levels of internal consistency were exhibited within each factor with statistically significant correlations between each of them. This information suggests sufficient reliability to justify implementation at a larger scale to allow for a more detailed analysis into the reliability and validity of the tool.

While it is currently not possible to draw conclusions from the mean scores offered by the participants in this study relative to alternative demographics, in general the participants agreed that they could exhibit the skills presented within the survey. Within the cohort, a potential gender difference is identified whereby males suggested a higher capacity in all cases however statistical significance was only observed for material reasoning and interconnected reasoning. This aligns with psychometric results within the field of spatial cognition [6, 8]. However as no psychometric instruments were used in this study, the accuracy of these judgements is unclear. It would be particularly interesting to examine gender differences pertinent to their metacognitive accuracy in recounting their cognitive abilities and how this translates into effective learning practices.

5. CONCLUSION

Considering the hypothesis that the field of technology and engineering education requires an entirely different mental discipline than in the broader education remit, it is paramount to uncover the nature of this cognitive architecture to justify its position within formal education. The 'MIND' framework affords an initial conceptual framework to guide this investigation. This pilot study ultimately aimed to determine any potential merit in the continuation of this research agenda and to identify potential areas of educational interest. With results indicating a high level of reliability and a potential alignment with pertinent psychometric literature, it appears that the 'MIND' framework and survey are appropriate tools. With a larger cohort of a wider demographic of students, further refinements can be made to support the rationalisation of the cognitive architecture espoused within engineering and technology education at both post-primary and higher level education.

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