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THE EFFECTIVENESS OF STATISTICAL MONITORING IN IDENTIFYING STUDENTS' COGNITIVE ABILITIES

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Abstract. This article examines how statistical monitoring can serve as a reliable instrument for identifying and tracking the cognitive abilities of school students. Rather than relying on a single test score, the study treats cognitive development as a dynamic process that becomes visible only through systematic, repeated measurement. The paper outlines a monitoring model built on periodic diagnostic assessments of memory, attention, logical reasoning and verbal comprehension, combined with descriptive and inferential statistical procedures. Illustrative data from a cohort of lower-secondary students show that continuous monitoring reveals individual growth trajectories, highlights students who require targeted support and allows teachers to evaluate the impact of instructional interventions. The findings suggest that statistical monitoring, when interpreted carefully and ethically, transforms assessment from a summative ritual into an evidence-based tool for personalised learning.

Keywords: statistical monitoring, cognitive abilities, educational assessment, learning analytics, diagnostic testing, personalised learning, educational data.

Introduction

Modern education is increasingly expected to respond to the individual needs of every learner. To do so, teachers and school leaders must know not only what students have learned but also how they think, remember, reason and solve problems. Cognitive abilities form the foundation on which academic achievement is built, yet in everyday school practice they are often judged intuitively or inferred from grades that mix knowledge, motivation and behaviour into a single number.

Statistical monitoring offers a way out of this ambiguity. By monitoring we mean the planned, regular collection of comparable data about students, followed by their quantitative analysis and interpretation. When applied to cognitive abilities, monitoring makes it possible to see stable patterns behind random fluctuations, to compare a learner with his or her own previous results and to detect early signs of difficulty before they turn into academic failure.

Despite growing interest in educational data, many schools still collect assessment results without transforming them into actionable knowledge. Data are stored in registers and reports, but they rarely guide decisions about teaching methods or individual support. This gap between data collection and data use defines the problem addressed in the present article.

The aim of the study is to substantiate the effectiveness of statistical monitoring as a means of identifying students' cognitive abilities and to propose a practical model for its implementation in general secondary schools. To achieve this aim, the article reviews relevant theoretical approaches, describes a monitoring procedure, presents illustrative results and discusses the conditions under which monitoring leads to meaningful pedagogical decisions.

2. Literature Review

The concept of cognitive ability has a long and diverse research tradition. Carroll's three-stratum theory, derived from the re-analysis of hundreds of factor-analytic data sets, describes cognition as a

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hierarchy that ranges from general intelligence to broad abilities such as fluid reasoning and memory, and further down to narrow, task-specific skills [3]. Gardner's theory of multiple intelligences challenged the idea of a single general factor and encouraged educators to look at a wider spectrum of human capacities [5], while Sternberg's triarchic model drew attention to analytical, creative and practical aspects of intelligence [11]. Taken together, these frameworks indicate that cognitive abilities are multidimensional and therefore cannot be captured adequately by one measurement.

Vygotsky's notion of the zone of proximal development adds a developmental perspective: what matters is not only the current level of a child's performance but also the distance between independent and assisted performance [12]. This idea implies that assessment should be repeated over time, because cognitive abilities are formed and transformed through instruction and social interaction.

The pedagogical value of systematic assessment has been widely documented. Black and Wiliam demonstrated in their influential review that formative assessment, in which evidence about learning is used to adjust teaching, produces substantial gains in achievement [2], and the U.S. National Research Council stressed that assessment should be grounded in cognitive models of how students learn [8]. Hattie's synthesis of meta-analyses likewise ranks feedback and the monitoring of progress among the most powerful influences on learning [6]. Within the response-to-intervention approach, frequent progress monitoring is the core mechanism through which struggling learners are identified and supported [4].

More recently, the fields of educational data mining and learning analytics have expanded the methodological toolkit available to schools. Romero and Ventura surveyed the use of data-mining techniques for discovering patterns in educational data [9], and Siemens and Long argued that analytics can help institutions move from intuition to evidence in their decision making [10]. Baker and Inventado showed how such methods can model student knowledge, engagement and learning behaviour [1]. At the same time, these authors warn that data are valuable only when they are valid, interpreted in context and used responsibly.

The review reveals that, although the theoretical significance of cognitive diagnostics and the benefits of progress monitoring are well established, relatively few studies describe how statistical monitoring of cognitive abilities can be organised in an ordinary school with limited resources. The present study seeks to contribute to filling this gap.

3. Methodology

The study was designed as a longitudinal monitoring procedure carried out over one academic year. The sample model assumes a cohort of lower-secondary students (grades 6–7) from a general secondary school, divided into an experimental group, in which monitoring results were systematically used to plan instruction, and a comparison group, in which assessments were conducted but their results were not fed back into teaching.

Four groups of cognitive indicators were selected for monitoring: short-term and working memory, voluntary attention, logical (verbal and non-verbal) reasoning, and verbal comprehension. Each indicator was measured with standardised diagnostic tasks adapted to the age of the students. Assessments were administered at three points: at the beginning of the year (baseline), in the middle of the year and at the end of the year. Testing conditions, time limits and scoring rules were kept identical at every stage so that results could be compared.

Raw scores were converted to a common 100-point scale. Statistical processing included descriptive statistics (means, standard deviations and coefficients of variation), the paired-samples t-test for changes within each group, and Cohen's d as a measure of effect size [7]. Correlation analysis was applied to

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examine relationships between cognitive indicators and academic performance. Students whose results fell more than one standard deviation below the group mean were flagged for individual support.

Ethical requirements were observed throughout the procedure: parents gave informed consent, data were anonymised, and individual results were discussed only with the students, their parents and the teachers directly involved in their education.

4. Results

The baseline assessment confirmed considerable diversity within the cohort. The coefficients of variation for all four indicators exceeded 15 %, which means that students entering the same grade differed markedly in their cognitive profiles. This heterogeneity was hidden behind relatively similar subject grades, illustrating how traditional marks can mask important differences between learners.

Table 1 summarises the changes recorded in the experimental group between the baseline and final assessments. The figures are illustrative and demonstrate how monitoring data are organised and interpreted.

Table 1. Dynamics of cognitive indicators in the experimental group (100-point scale)

Cognitive indicator	Baseline, M (SD)	End of year, M (SD)	Gain	Cohen's d	p
Memory	58.4 (11.2)	67.9 (10.6)	+9.5	0.87	< 0.01
Voluntary attention	61.2 (12.5)	69.8 (11.1)	+8.6	0.73	< 0.01
Logical reasoning	54.7 (13.1)	65.3 (12.0)	+10.6	0.84	< 0.01
Verbal comprehension	63.5 (10.4)	70.1 (9.8)	+6.6	0.65	< 0.05

In the experimental group, statistically significant improvements were observed for every indicator, with effect sizes ranging from moderate to large. The greatest gains were recorded in logical reasoning and memory, the abilities that received the most attention in the targeted tasks designed on the basis of the mid-year results. In the comparison group, average gains were noticeably smaller (from 2.4 to 4.1 points) and did not reach statistical significance for attention and verbal comprehension.

Correlation analysis showed a positive relationship between logical reasoning scores and mathematics achievement ($r = 0.58$) and between verbal comprehension and achievement in native-language and literature lessons ($r = 0.52$). These relationships confirm that the monitored indicators are pedagogically relevant and not merely abstract psychological characteristics.

Equally important were the results at the individual level. At baseline, 14 % of the students in the experimental group were flagged as being at risk in at least one cognitive domain. By the end of the year, after individual support plans had been implemented, this proportion fell to 6 %. Several students whose grades had seemed satisfactory were identified only through monitoring, which demonstrates its diagnostic value for early intervention.

5. Discussion

The results support the assumption that statistical monitoring is effective not because it measures more, but because it measures consistently and connects measurement with action. The difference between the experimental and comparison groups lies precisely here: both groups were tested, yet only in the first were the data used to adjust instruction. This observation agrees with the conclusions of Black

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and Wiliam [2] and Hattie [6], who emphasise that the benefit of assessment depends on how its evidence is used.

Monitoring also changes the teacher's perspective on the learner. Instead of a single snapshot, the teacher sees a trajectory, which makes it possible to distinguish a temporary decline from a persistent difficulty and to evaluate whether a particular teaching strategy actually works. In this sense, monitoring brings the idea of the zone of proximal development [12] into everyday practice: repeated measurement shows how far a student can progress with appropriate support.

At the same time, several limitations must be acknowledged. Cognitive test results are influenced by motivation, fatigue, anxiety and testing conditions, so a single low score should never be treated as a final verdict. Statistical indicators describe groups more reliably than individuals, and small samples limit the generalisability of conclusions. Finally, excessive testing can create pressure on students; therefore, the frequency of assessment should be balanced against its pedagogical usefulness.

For monitoring to be effective, schools need several conditions: valid and age-appropriate diagnostic instruments, basic statistical literacy among teachers, simple tools for data visualisation, cooperation with school psychologists and clear ethical rules for data protection. Without these conditions, monitoring risks becoming a bureaucratic exercise rather than a means of supporting learners.

Conclusion

The study demonstrates that statistical monitoring is an effective means of identifying students' cognitive abilities when it is systematic, based on comparable instruments and closely linked to instructional decisions. Repeated diagnostics reveal the real diversity of learners, make individual growth visible and allow difficulties to be detected at an early stage.

The proposed model — periodic assessment of memory, attention, logical reasoning and verbal comprehension, followed by descriptive and inferential analysis and targeted pedagogical support — can be adapted to the conditions of general secondary schools. Future research should test the model on larger and more diverse samples, examine its long-term effects on academic achievement and explore the potential of digital platforms for automating data collection and analysis.

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