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GRADUAL REDUCTION OF INSTRUCTIONAL REDUNDANCY AS A PEDAGOGICAL MECHANISM FOR DEVELOPING LEARNER AUTONOMY IN A SPIRAL COMPUTER SCIENCE CURRICULUM (GRADES 7-8)

Teaching methods

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Abstraction

This study examines the impact of the gradual reduction of instructional redundancy on the development of cognitive autonomy among Grade 7-8 students within a spiral computer science curriculum.

The aim of the study was to determine whether a gradual decrease in task algorithmization facilitates the development of analytical strategies without compromising academic performance. The research was conducted in an Action Research format over two academic years (n = 45) and included three consecutive cycles with a progressive transformation of pedagogical support.

The analysis of performance dynamics revealed an increase in the proportion of analytical solutions, a higher frequency of pre-task planning, and a reduction in clarifying questions, while maintaining stable academic achievement levels.

The findings suggest that reducing instructional support can be considered a controlled mechanism for developing learner autonomy and intra-disciplinary cognitive transfer. The practical significance of the study lies in proposing a staged model for transitioning from algorithmic guidance to strategic solution design.

Key words: instructional redundancy reduction; learner autonomy; scaffolding; metacognitive planning; higher-order thinking; spiral curriculum; cognitive transfer.

Introduction

Analysis of the Grade 7 curriculum plan revealed a predominance of “understanding” and “application” level objectives according to Bloom’s taxonomy: working by example, using predefined formulas, and template-based programming.

In Grade 8, the proportion of higher-order objectives increases, including analysis, evaluation, and creation. Students are expected to independently derive formulas, design programs without predefined structures, and evaluate algorithm correctness.

Observations at the beginning of Grade 8 identified a persistent dependence on step-by-step instructions: in the absence of explicit algorithms, students demonstrated an increase in clarifying questions and decreased confidence.

The study addresses the contradiction between the need for structured support in early learning and the development of higher-order analytical skills, hypothesizing that excessive algorithmization in Grade 7 may hinder this transition.

Aim: to determine whether the gradual reduction of instructional redundancy in Grade 7 supports the successful attainment of higher-order objectives in Grade 8 and enables the realization of spiral progression through intra-disciplinary transfer.

Research questions: 1) Does reducing algorithmization in Grade 7 prepare students for analytical tasks in Grade 8? 2) Does cognitive transfer occur between Grade 7 and Grade 8 topics? 3) Is academic performance maintained when task structure is reduced?

According to scaffolding theory (Bruner, 1986), instructional support is temporary and gradually transfers control to the learner.

Self-regulated learning theory (Zimmerman, 2002) conceptualizes learning as a process involving planning, monitoring, and reflection. Metacognitive planning serves as a key mechanism for transitioning from externally structured actions to internally regulated strategies (Vilkova, 2020; Bagramyants, 2025).

The revised Bloom's taxonomy (Anderson & Krathwohl, 2001) describes progression from application to analysis, evaluation, and creation. Excessive algorithmization reinforces the application level and reduces the need for independent strategy selection.

The integration of these frameworks allows the reduction of instructional redundancy to be interpreted as a controlled transformation of external regulation into internal cognitive mechanisms that support autonomy and higher-order thinking.

From a cognitive load perspective (Sweller, 2010), reducing instructional redundancy may decrease extraneous load while increasing germane load. Future research should include empirical measurement of subjective cognitive load to clarify this mechanism.

Methodology

The study involved 45 students (three classes of 15). Implementation period: Grade 7: 2024-2025 academic year (four terms) and Grade 8: 2025–2026 academic year (terms 1-3).

Data collection methods included: analysis of summative assessments, classroom observations, student questionnaires (self-assessment of autonomy), quantitative analysis of clarifying questions, comparative analysis of problem-solving strategies. Operational criteria were developed to assess cognitive level and autonomy.

Analytical level (Bloom's taxonomy) was identified when at least two indicators were present: task decomposition, justification of algorithm choice, identification of conditions of applicability, or verification of correctness. Evaluation and creation levels included comparison of strategies or development of alternative solutions.

Cognitive autonomy was assessed through:

- frequency of pre-task planning
- number of independent attempts before seeking help
- reduction in clarifying questions
- justification of strategy

Metacognitive planning was identified when students produced a written description of the solution strategy (2-5 sentences) before task execution.

Coding reliability was ensured through re-analysis of 20% of responses after two weeks (91% agreement). Inter-rater reliability was not conducted.

The study employed a longitudinal design without a control group, limiting causal inference.

Participation was voluntary, data was anonymized, and analysis was conducted on aggregated indicators. Cognitive load was not directly measured.

The study was conducted within an Action Research framework over two academic years and comprised three consecutive cycles structured according to the model "planning - action - observation - analysis - reflection" with iterative adjustments to instructional design at each stage.

Cycle 1 (Grade 7, Terms 1-2): Diagnosis of Dependence

The first cycle aimed to identify students' dependence on step-by-step instructional support. Tasks with full, partial, and minimal instruction (task statement only) were implemented. In the units' "Spreadsheets" and "Linear Algorithms," examples of formulas and predefined flowcharts were gradually removed.

Observations showed an increase in clarifying questions (5-7 per lesson under minimal instruction), slower task completion, and more frequent logical errors. Analysis indicated a predominance of the application level and limited capacity for independent solution design.

These results informed the redesign of instruction toward a more gradual reduction of support and the introduction of metacognitive elements.

Cycle 2 (Grade 7, Terms 3-4): Gradual Reduction

A three-stage model was introduced: "worked example - partial template - task-only condition". In programming tasks, students were required to provide a brief written description of their solution strategy (3-5 sentences) prior to coding. In selected tasks, step-by-step instructions were replaced with outcome-based criteria.

By the end of the academic year, the number of clarifying questions decreased by 27%, students' responses became more explicitly justified, and the use of draft work increased. A shift toward analytical processing was observed, as students began to decompose tasks prior to implementation. The mean summative assessment score remained stable. These observations informed the continuation of gradual reduction and structured planning in the subsequent cycle.

Cycle 3 (Grade 8, Terms 1-3): Transfer and Spiral Progression

In the third cycle, step-by-step algorithms were fully removed in analytically oriented topics ("Information Encoding," "Iterative Algorithms," "Arrays"), and assessment included both correctness and strategy.

Clarifying questions decreased by 43% compared to the beginning of Grade 7, and 72% of students consistently engaged in pre-task planning. Evidence of transfer was observed in array-related tasks, where students applied aggregation logic previously acquired in spreadsheet work (e.g., SUMIF). Students increasingly decomposed problems, evaluated algorithm correctness, and developed alternative solutions.

If the development of the study is represented over time, it can be described as follows: diagnosis of dependence (beginning of Grade 7), controlled reduction (end of Grade 7), verification of transfer to higher-order objectives (Grade 8), and confirmation of functional spiral progression.

Table 1 illustrates functional spiral progression: the recurrence of topics is accompanied by an increase in cognitive level. Thus, the study evolved from problem identification to the testing of a systemic hypothesis regarding cognitive transfer.

Table 1. Cognitive Transfer (Spiral Progression)

Grade 7	**Grade 8**	**Type of Cognitive Transfer**	**Bloom's Level**	**Type of Cognitive Operation**
SUMIF and COUNTIF functions (spreadsheets)	Summation and selection of array elements	Model → algorithm → code	Application → Analysis	Generalization and formalization
Conditional statements	Conditional loops	Logical structure → iterative process	Understanding → Analysis	Dynamic decomposition
Algorithm flowcharts	Loop tracing	Visual model → formal implementation	Application → Evaluation	Representational transfer
Website creation	Information encoding	Data representation → binary model	Understanding → Analysis	Abstraction of representation level
Sorting in spreadsheets	Selection in arrays	Data processing operation → universal algorithm	Application → Creation	Algorithmic generalization

The inclusion of the column "Type of Cognitive Operation" makes it possible to clarify that spiral progression is realized not only through the recurrence of topics, but also through the increasing complexity of forms of abstraction and modes of cognitive processing.

Results

To assess the dynamics, the following indicators were used: the average number of clarifying questions per lesson, the proportion of students demonstrating pre-task planning, the mean score of summative assessment, and the proportion of analytical responses (analysis level and above according to Bloom's taxonomy; see Table 2).

Table 2. Dynamics of Indicators Across the Research Cycles

Indicator	**Beginning of Grade 7**	**End of Grade 7**	**Grade 8 (Term 3)**
Average number of clarifying questions per lesson	6–7	4	3
Proportion of students demonstrating pre-task planning	18%	52%	72%
Mean summative assessment score (10-point scale)	7.8	7.9	8.1
Proportion of analytical responses (analysis level and above)	24%	48%	74%

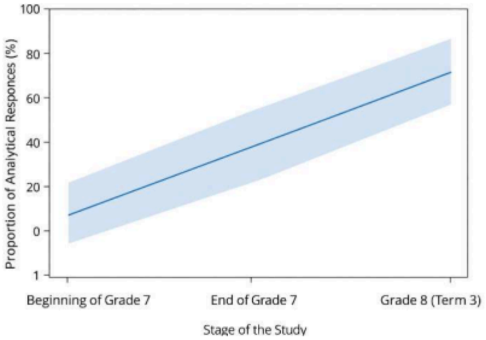

Figure 1. Dynamics of the Proportion of Analytical Responses (Grades 7-8)

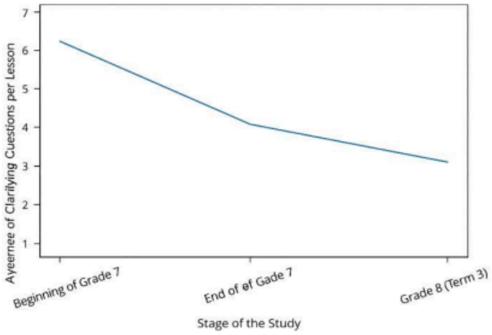

Figure 2. Decrease in the Average Number of Clarifying Questions per Lesson

The analysis was conducted using individual student-level data ($n = 45$). The proportion of analytical responses increased by 50 percentage points (relative increase: +208%). Calculations were based on aggregated individual indicators ($n = 45$).

A significant correlation was identified between pre-task planning and the analytical nature of solutions ($r = 0.62$; $p < 0.001$). A paired-samples t-test demonstrated a statistically significant increase in the proportion of analytical responses from the beginning of Grade 7 to Grade 8: $t(44) = 13.4$; $p < 0.001$.

Additionally, the effect size (Cohen's d) was calculated as $d = 2.0$, corresponding to a very large effect according to Cohen's classification. The effect size was computed for dependent samples using the standard deviation of the differences (M_diff / SD_diff). The 95%

confidence interval for d was [1.52; 2.48], confirming the robustness of the effect while maintaining its large magnitude.

It should be noted that the calculation was based on proportions of analytical responses, which, given substantial differences between measurements, may lead to large effect sizes. The data obtained indicates a substantial difference between measurement points. However, in the absence of a control group, interpretation of the effect should be approached with caution. Testing of the distribution did not reveal critical deviations from normality, which justified the use of parametric analysis.

Further analysis of individual trajectories showed that the most pronounced growth in analytical performance was observed among students who initially demonstrated a higher dependence on instructional support, thereby indirectly reinforcing the interpretation of the intervention as a significant factor in the observed changes.

A conditional division of the sample into two subgroups based on the initial level of cognitive autonomy (below and above the median at the beginning of Grade 7) revealed differences in growth dynamics. In the subgroup with initially lower autonomy, the proportion of analytical responses increased from 18% to 70% (+52 percentage points), whereas in the subgroup with higher initial autonomy it increased from 30% to 78% (+48 percentage points). The more pronounced relative growth in the first subgroup indirectly supports the significance of the pedagogical intervention.

These differences in growth rates are descriptive in nature and require further statistical verification in a larger sample to confirm a potential interaction effect between time and initial autonomy level.

The observed dynamics align temporally with the stages of pedagogical intervention: a reduction in clarifying questions (-43%), a fourfold increase in pre-task planning, and stable average scores collectively indicate the development of learner autonomy without a decline in learning outcomes.

The findings confirm a substantial increase in analytical performance, the preservation of average achievement, and stable intra-disciplinary transfer. Therefore, the research questions received empirical support.

Discussion / Conclusion

The reduction of instructional redundancy was accompanied by a transformation in the organization of learning activity: step-by-step algorithms were replaced with outcome-based criteria, the teacher’s role shifted toward facilitating strategic thinking, and pre-task planning was institutionalized as a mandatory component of task execution. These changes supported a transition from predominantly application-level performance to sustained engagement with analysis and evaluation.

Students increasingly identified task parameters independently, transferred previously acquired models, and developed alternative solutions. Evidence of intra-disciplinary transfer was observed, particularly between spreadsheet functions and array processing. Tasks without step-by-step guidance revealed emerging problem decomposition skills, and improvements in oral argumentation indicated the development of communicative-cognitive components of learning activity.

The most effective elements of the intervention included: (1) a three-stage reduction model (“worked example - partial template - task-only condition”), (2) mandatory pre-task planning, and (3) the replacement of procedural instructions with outcome-based criteria. These elements supported a balance between instructional guidance and learner autonomy.

During the transition phase, a temporary slowdown in performance and an increase in errors were observed, highlighting the necessity of gradual implementation. Approximately 15% of students required differentiated support.

The absence of a control group limits causal interpretation. The observed dynamics may also be influenced by cognitive maturation, accumulated subject-specific experience, and teacher-related factors.

From a practical perspective, the findings support the integration of gradual instructional reduction into lesson design, alignment with Bloom's taxonomy, and structured reflection on problem-solving strategies. Instructional design should also include differentiated support and consider cognitive autonomy as an indicator of learning quality.

Future research should include larger samples, control groups, and direct measurement of cognitive load.

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