AI Literacy and Creative Coding as Predictors of Primary Students' Classroom Engagement

A profile analysis of block-based programming knowledge and active learning engagement

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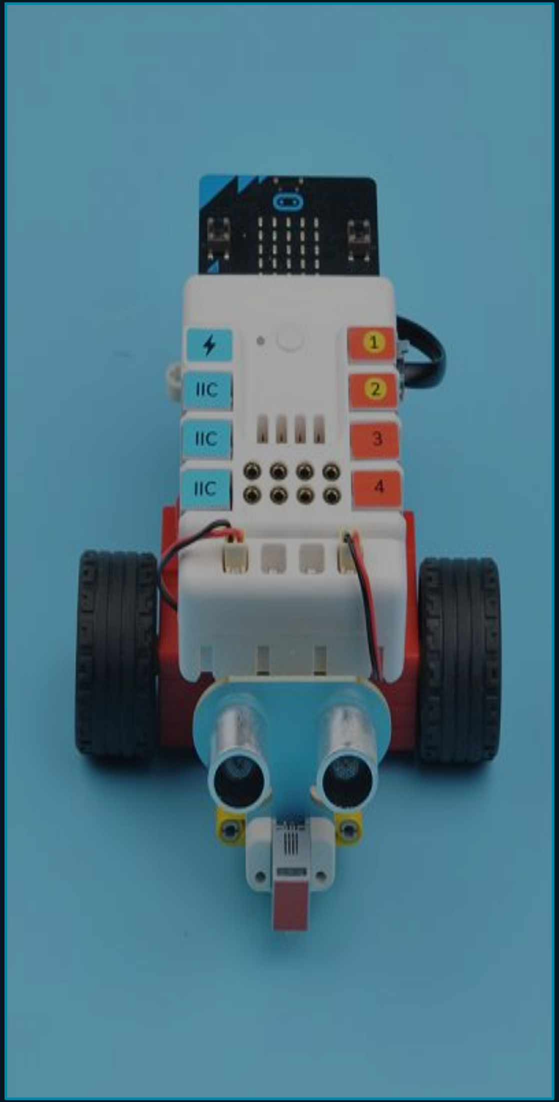


Why this study matters

Early computing education needs evidence about sustained, meaningful engagement

The challenge

- Block-based programming and robotics are increasingly present in primary classrooms.
- Engagement is heterogeneous: participation, confidence, and conceptual clarity do not develop evenly.
- Educators need empirically grounded profiles to design differentiated computing experiences.

Key framing: engagement is treated as a pedagogical outcome shaped by both perceived competence and active participation.

Theoretical anchors

From constructionist production to computational thinking and engagement

Constructionism

Learning through building, debugging, and sharing artifacts

Computational thinking

Sequencing, abstraction, decomposition, logic, and error detection

Digital competence

Knowledge, skills, and attitudes for critical, creative, responsible technology use

Student engagement

Behavioral participation, affective involvement, and cognitive investment

Creative coding becomes pedagogically powerful when it is active, reflective, and scaffolded.

Research questions

A person-centered approach to differentiated digital engagement

RQ1

How are self-reported programming knowledge and active learning engagement distributed among primary students?

RQ2

What learner profiles emerge from the joint configuration of these two dimensions?

RQ3

How do those profiles help interpret differentiated patterns of classroom engagement?

Study design and sample

Quantitative, cross-sectional, non-experimental design

1,009	**9–11**	**2024–2025**	**51.4% / 48.6%**	**Spain**
students	years old	academic year	female / male	public schools

Sampling focus

- Upper-primary classrooms
- Introductory programming activities
- Block-based environments such as Scratch

Ethical conditions

- School authorization
- Student informed assent
- Bioethics approval from UNED

Source: short paper study design and method section.

Measurement model

Two inferential dimensions from a broader questionnaire

Used in analyses

Self-reported knowledge of block-based programming

Examples: sequences, blocks, debugging, perceived ability to work with visual coding tasks.

Used in analyses

Engagement in active learning environments

Examples: participation, collaboration, hands-on exploration, and classroom activity involvement.

Not used as direct AI measure

Perceptions of programming and machine learning

Part of the broader instrument, but not operationalized as direct AI literacy in this article.

All scales used a 5-point Likert response format; internal consistency was satisfactory (Cronbach's alpha > .75).

Analytical workflow

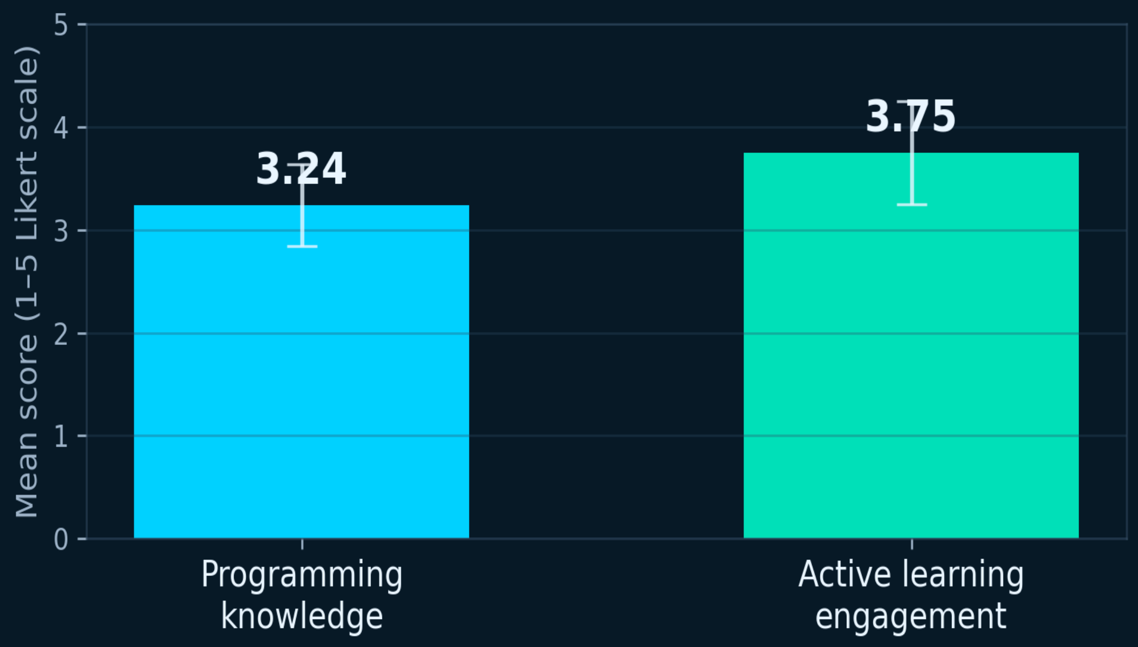
Clustering as a parsimonious profile strategy

1. **Standardize variables**
   Programming knowledge + active learning engagement
2. **Hierarchical clustering**
   Ward's method to explore group structure
3. **K-means optimization**
   Refine cluster centroids and membership
4. **ANOVA checks**
   Assess differences among profiles
5. **Discriminant analysis**
   Internal separability check, not external validation

Interpretation rule: classification accuracy describes internal separation, not external predictive validity.

Descriptive pattern

Active participation slightly exceeds perceived coding proficiency



Main descriptive result

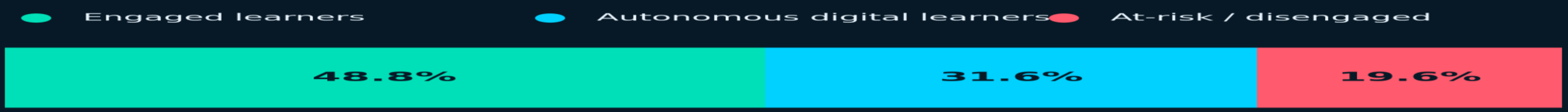
- Students report relatively high engagement in technology-supported learning.
- Perceived programming knowledge is moderately high, but lower than active engagement.
- Gender differences are minimal and educationally small.

Interpretation: students may be willing to participate before they feel fully competent as coders.

Source: study results, N = 1,009.

Three learner profiles

Joint configurations of coding knowledge and active learning engagement



48.8% n = 492

Engaged Learners

Programming knowledge: 3.15
Active learning engagement: 3.97

31.6% n = 319

Autonomous Digital Learners

Programming knowledge: 3.67
Active learning engagement: 3.97

19.6% n = 198

At-Risk / Disengaged

Programming knowledge: 2.77
Active learning engagement: 2.84

ANOVA confirmed statistically significant profile differences for both dimensions ($p < .001$).

Internal separability

A strong profile solution with a clear methodological boundary

99.8%

internal classification accuracy

Linear discriminant analysis strongly separates the three learner profiles.

Important boundary condition

- The same variables were used to create and classify the clusters.
- No cross-validation or holdout sample was implemented.
- The result supports internal coherence, not external predictive power.

Rigorous interpretation: robust internal structure, cautious external claims.

Pedagogical translation

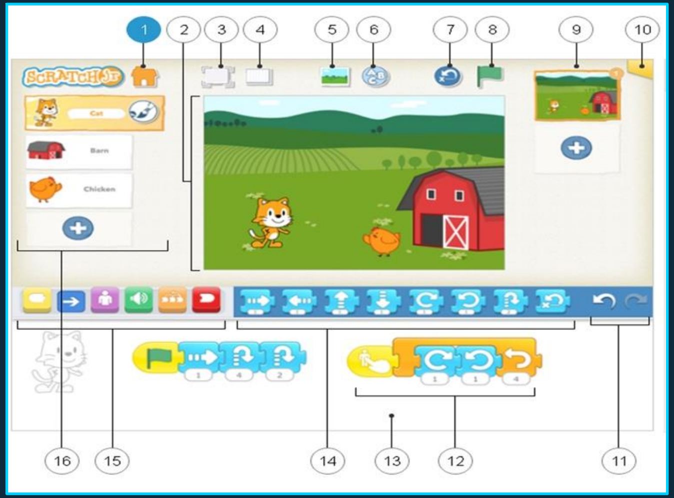
Differentiated instruction for distinct engagement profiles

Autonomous Digital Learners	Open-ended challenges; peer mentoring; extension tasks; design constraints
Engaged Learners	Conceptual consolidation: sequences, loops, conditionals, debugging, reflection
At-Risk / Disengaged	Short tasks; explicit modeling; visual supports; pair programming; formative feedback

Design principle: make success attainable, visible, and progressively more complex.

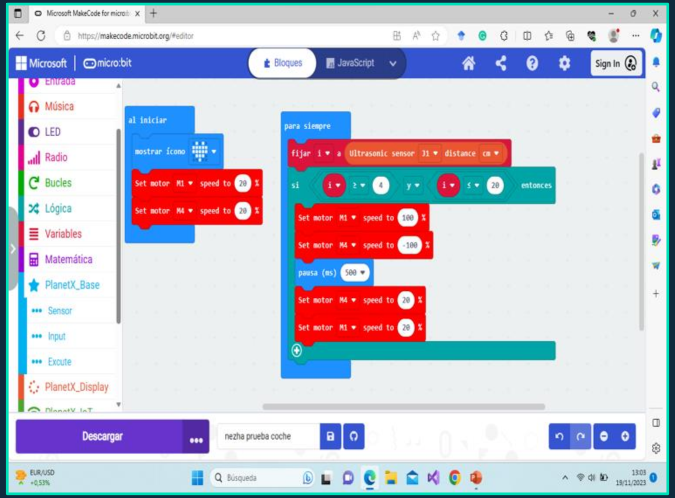
Activity examples from the teaching materials

Creative coding as visible, manipulable, and collaborative computation



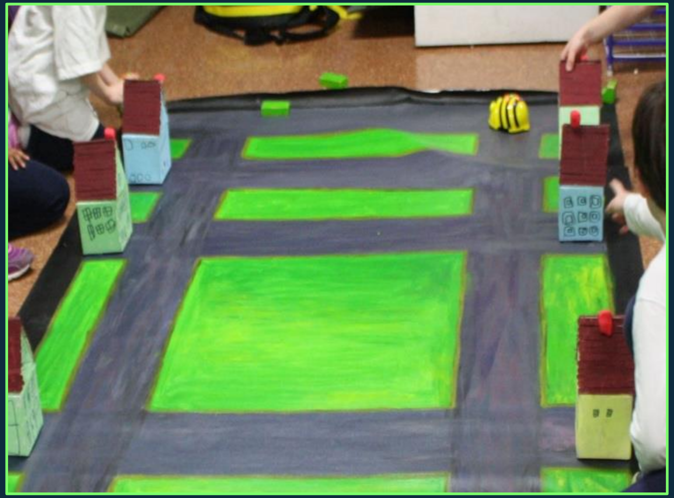
ScratchJr / visual block sequencing

Stories, sprites, sequence, event logic



micro:bit + MakeCode

Sensors, conditionals, motors, debugging



Robotics problem solving

Navigation, testing, iteration, collaboration

These activities operationalize computational thinking through tangible artifacts, not abstract definitions alone.

From creative coding to AI readiness

A defensible bridge, not an empirical overextension

Blocks
visible commands

→

Algorithms
ordered procedures

→

Sensors + data
inputs from the world

→

Debugging
testing and revision

→

AI concepts
models and intelligent systems

Caution The study supports early digital competence and AI-related readiness. It does not directly measure AI literacy or causal learning gains in AI understanding.

The bridge is pedagogical: coding activities can prepare the conceptual ground for later AI education.

Limitations

Boundaries that make the contribution scientifically credible

Self-report measure

Perceived programming knowledge may differ from actual coding performance.

Cross-sectional design

The analysis identifies associations, not causal direction.

Internal validation only

Discriminant analysis checks separation, not external predictive accuracy.

AI literacy not directly measured

Conclusions are bounded to creative coding and active learning engagement.

Future work: performance tasks, code artifacts, learning analytics, and longitudinal designs.

Contribution

A scalable profile framework for primary computing education

Empirical

Identifies three differentiated student profiles using two central dimensions of early digital competence.

Methodological

Shows how simple profile analysis can support interpretable educational evidence without overstating causal inference.

Pedagogical

Translates learner heterogeneity into differentiated scaffolding for Scratch, robotics, and active learning tasks.

Core message: engagement is strongest when participation is paired with progressively consolidated coding knowledge.

Thank you

Questions and discussion

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Take-away: profile-informed creative coding can make early computing education more inclusive, coherent, and engaging.