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An Event-Centered Learning Analytics Approach to Programming Language Transitions in a Hybrid Environment

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Abstract: This exploratory study examines primary school students' emotional experience when learning programming in a hybrid environment combining block-based programming (BBP) and text-based programming (TBP). The aim is twofold: first, to analyze the emotional indicators associated with the use of each programming modality, and second, to examine how these indicators evolve during transitions between them. Data were collected from five students using a system measuring stress and attention, synchronized with programming activities. The results show that, within a hybrid environment, the overall emotional profiles observed in BBP and TBP remain comparable, suggesting emotional continuity between the two modalities. The analysis of transition events further indicates that emotional changes depend more on the pedagogical context and the timing of the transition than on the programming language itself. These findings highlight the potential of hybrid programming environments to support an emotionally sustainable transition toward text-based programming.

Keywords: block-based programming, text-based programming, emotional indicators, learning analytics, multimodal data, hybrid programming environment

1. Introduction

In primary education, programming is generally taught using block-based programming environments (BBP), which are widely recognized as suitable for young learners and novices. However, achieving proficiency in text-based programming (TBP) remains a central objective of programming education.

The transition from BBP to TBP is widely acknowledged as a challenging step in the learning process, and various approaches have been proposed to support this transition. The use of two separate environments can nevertheless lead to differences in learners' emotional experiences, notably an increase in stress when moving to a text-based environment. To address these difficulties, hybrid programming environments have been developed to enable a more gradual transition between BBP and TBP within a single environment.

Despite this development, few studies have examined students' emotional experiences when using hybrid programming environments, particularly during the specific moments of transition between BBP and TBP. Accordingly, this exploratory study adopts an event-centered learning analytics approach and aims to leverage emotional indicators to better understand the pedagogical events represented by BBP–TBP transitions within a hybrid programming environment.

2. Background and context

Programming instruction at the primary school level relies predominantly on BBP, which are widely regarded as appropriate for novice learners due to the removal of syntactic constraints and the use of manipulable visual representations (Grover & Pea, 2013; Weintrop & Wilensky, 2017). Nevertheless, developing proficiency in TBP remains a key goal of programming education, and the transition from BBP to TBP is identified as a critical stage in the learning process (Lin & Weintrop, 2021).

Numerous studies have shown that skills acquired through BBP do not automatically transfer to TBP. Transitioning to TBP requires explicit management of syntax and code structure, which can pose significant challenges for learners and calls for targeted pedagogical support (Lin & Weintrop, 2021). A recent systematic review highlights the wide range of strategies proposed to support this transition, while emphasizing that no single approach can be considered universally optimal and that their effectiveness strongly depends on the learning context (Strong et al., 2025).

A substantial proportion of these strategies relies on the use of two separate environments, one dedicated to BBP and another to TBP. While this separation allows each language to be addressed according to its specific characteristics, it may also intensify the discontinuity between the two modalities. In such cases, changes in both environment and representation can constitute an additional challenge for learners, particularly during their initial experiences with TBP (Lin & Weintrop, 2021).

Beyond cognitive aspects, some research has focused on the emotional dimension of learning to program. Studies by Umezawa (2021) indicate that the use of TBP, especially when implemented in environments distinct from those used for BBP, can be associated with higher levels of stress, particularly as task complexity increases. However, these studies primarily examine situations in which BBP and TBP are used separately, without specifically addressing the moments of transition between these modalities.

In this context, hybrid programming environments have been proposed as intermediate solutions aimed at reducing the discontinuity between BBP and TBP. These environments allow learners to switch between languages within a single working framework, thereby supporting a more gradual transition (Lin & Weintrop, 2021).

Despite growing interest in hybrid environments, empirical studies examining learners' emotional experiences during their use remain limited. Emotional responses observed during transitions between BBP and TBP within the same environment are still underexplored (Strong et al., 2025). This lack of empirical evidence constrains the development of pedagogical recommendations grounded in students' lived experiences during these transitions.

3. Research questions

Building on existing studies and the identified limitations in the emotional analysis of hybrid programming environments, this exploratory study aims to address the following research questions: (1) In a hybrid programming environment, how can emotional indicators be used to characterize programming using BBP and TBP? (2) How do students' emotional indicators evolve during transitions between BBP and TBP within a hybrid programming environment?

4. Methodology

4.1 Participants

This exploratory study aims to conduct a fine-grained, temporal, and individual analysis of students' emotional trajectories during programming activities in a hybrid environment. To this end, the study focuses on four fifth-grade students and one sixth-grade student, selected to reflect a diversity of learning profiles in programming. The choice of a small sample size responds to the objective of conducting an in-depth analysis of the situations experienced by each student rather than achieving statistical generalization. To characterize this diversity,

students were positioned according to their initial understanding of programming concepts and their progression based on the results of the Conceptual Computational Thinking Test (CCTT), adapted from CcTt (El-Hamamsy et al., 2022), administered before and after the project. The identified profiles (Table 1) include students with low or high initial levels, combined with strong, moderate, or stable progression. These profiles were used as criteria to construct a varied sample, allowing the observation of contrasted programming situations.

Table 1. *Student profiles based on initial level and progression on the CCTT*

Profile	Initial level	Progression	Students
P1	Low	High	A, B
P2	Low-Medium	Stable	C
P3	High	High	D
P4	Low-Medium	Moderate	E

4.2 Learning design and hybrid programming environment

The programming activities were implemented in Microsoft MakeCode, which enables switching between BBP and TBP within the same interface with a single click. Lessons were conducted through a safari simulation project in which students designed and programmed a rail system to explore the environment. This context provided an engaging task while progressively mobilizing core programming concepts. Students completed three one-hour programming sessions. Each session introduced a concept in BBP, followed by an exercise and a similar task in TBP, while allowing students to switch between languages according to their needs.

4.3 Measurement tools

The unit of analysis consists of transition events between BBP and TBP occurring during instructional activities in the hybrid environment. Physiological and behavioral indicators were collected using LaCause (Olive), an emotional analysis system based on remote photoplethysmography (rPPG) and movement data captured via the computer's camera. The system continuously estimates stress (three-level scale: 1–3) and attention (binary scale: 0–1). Their combination defines four emotional categories (calm, interest, dispersion, and stress), used here as interpretative lenses to analyze pedagogical transitions. Emotional indicators were synchronized with students' screen recordings to precisely identify programming phases and transition moments.

4.4 Ethical considerations.

Ethical approval was obtained from the institutional ethics committee of the university prior to data collection. Written informed consent was obtained from students and their guardians. Emotional indicators derived from video and physiological estimates were used solely for research purposes, anonymized prior to analysis, and were not used for grading or individual evaluation. Participants were informed that they could withdraw from the study at any time.

5. Results

5.1 Types of emotions in BBP and TBP

The following results focus on the distribution of emotional indicators derived from stress and attention measures observed during the use of BBP and TBP in a hybrid programming environment (Table 2).

Table 2. *Proportions of emotional states in BBP and TBP*

Students	BBP				TBP			
	Calm	Interest	Dispersion	Stress	Calm	Interest	Dispersion	Stress
A	0.07	**0.39**	**0.55**	0.00	0.22	**0.36**	**0.42**	0.00
B	0.08	**0.51**	0.07	**0.35**	0.13	**0.51**	0.08	**0.27**
C	**0.37**	**0.40**	0.12	0.11	**0.30**	**0.37**	0.15	0.18
D	**0.32**	**0.47**	0.09	0.12	**0.29**	**0.40**	0.08	0.23
E	**0.41**	0.24	0.20	0.14	**0.32**	**0.35**	0.18	0.16

For four students (A, B, C, and D), the emotional indicator profiles observed in BBP and TBP remain globally similar. For these students, the dominant emotional indicators remain unchanged across the two programming modalities, suggesting that the transition to TBP, within a hybrid environment, does not lead to a major modification of the overall emotional climate.

Student E, however, presents a more pronounced change in emotional indicator profile between BBP and TBP. Although interest remains the dominant emotion in both modalities, TBP is associated with a higher level of stress compared to BBP. This stress nevertheless remains secondary to interest, indicating sustained engagement despite a higher emotional load. This profile highlights that, for some students, TBP may involve a specific emotional cost without compromising involvement in the activity.

Overall, these results indicate that, in a hybrid programming environment, the global emotional indicators observed in BBP and TBP remain comparable for most students, while still revealing individual variations depending on learner profiles.

5.2 Emotional changes during transitions between BBP and TBP

The second analysis examined variations in emotional indicators around transition events between BBP and TBP. Transitions were classified into three types: (1) transitions back to BBP (TBP → BBP); (2) transitions toward TBP (BBP → TBP); and (3) rapid back-and-forth transitions occurring within a one-minute interval (TBP ↔ BBP). For types (1) and (2), emotional indicators were computed within a 30-second window before (t = −30 to t = 0) and after (t = 0 to t = 30) the transition. For type (3), successive switches within one minute were grouped as a single event to capture rapid switching behavior as a coherent episode rather than independent transitions.

Figures 2, 3, and 4 present aggregated emotional trajectories centered on the transition (t = 0), including all observed transitions across participants. Identical trajectories are represented by thicker lines to indicate recurrence. Black lines correspond to non-problematic situations, whereas red lines indicate problematic situations identified during programming. Transitions were additionally categorized as student-initiated (autonomously triggered by students) or instruction-driven (occurring in response to teacher guidance). However, no distinctive emotional patterns were observed across these categories; therefore, this distinction is not represented in the figures.

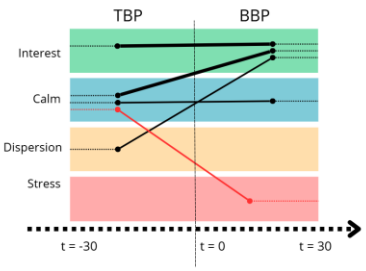

Figure 2. TBP → BBP

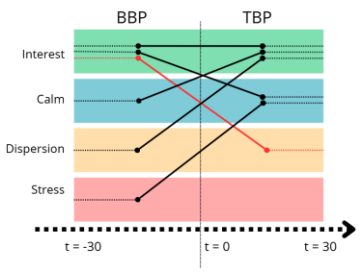

Figure 3. BBP → TBP

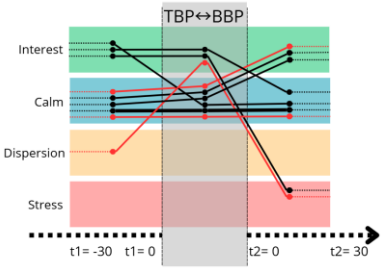

Figure 4. TBP ↔ BBP

Transitions back to BBP occur mainly when students face difficulties related to the content of the text-based code, requiring partial or complete reconstruction, logical verification, or targeted modifications. From an emotional perspective, these transitions are generally characterized by stability or convergence toward interest. States of calm or dispersion tend to

shift toward interest after the transition, suggesting cognitive and emotional re-engagement. In one case, complete code reconstruction is accompanied by an increase in stress, reflecting the initial cognitive cost of restarting. However, this phase tends to be transitory and to evolve toward calmer or more engaged emotional states, particularly when reconstruction clarifies the program structure.

Transitions toward TBP occur either as part of instructional guidance or through autonomous consultation of code created in BBP. Observed trajectories show stabilization of interest or shifts toward calm and interest, indicating that switching to TBP does not necessarily produce emotional overload when grounded in an understood solution. When transitions follow successful problem resolution, stress often shifts toward interest. Conversely, when the transition is imposed while difficulties remain unresolved, the figures show occasional shifts toward dispersion, interpreted as temporary disorganization caused by a disruption in the activity flow rather than by sustained disengagement.

Back-and-forth transitions between BBP and TBP are generally initiated by students to compare the two code representations. When these transitions occur outside problematic situations, the observed trajectories suggest indicating emotional stability, mainly between calm and interest. In such cases, students use the two representations in a complementary manner to compare, verify, or observe program structure, without marked emotional changes. In contrast, when back-and-forth transitions occur after unsuccessful code execution, the figures reveal more complex trajectories involving shifts toward dispersion, which may evolve into stress when difficulties persist. These trajectories may reflect increasing cognitive uncertainty, linked to difficulties in identifying the source of the problem despite repeated transitions between the two languages.

6. Discussion

This study adopts an event-centered learning analytics perspective, in which emotional indicators are not considered learning outcomes, but analytical tools used to interpret the pedagogical situations experienced by students. Stress and attention data are mobilized to make visible state variations associated with programming situations in BBP and TBP. Within this framework, the discussion is structured around two research questions: (RQ1) how emotional indicators characterize programming situations in BBP and TBP within a hybrid environment, and (RQ2) how these indicators evolve during transition events between the two modalities.

Regarding the first research question, the results show that, within a hybrid programming environment, the overall emotional distributions observed in BBP and TBP remain comparable across student profiles. This relative stability suggests emotional continuity between the two modalities and indicates that TBP is not intrinsically associated with a more negative emotional experience for primary school students when integrated into a hybrid environment. In contrast to previous studies reporting increased stress during TBP use in separate environments (Umezawa, 2021), the present findings suggest that when the transition to TBP is mediated within a single environment, it can occur without marked emotional overload. From a pedagogical perspective, these results support the idea that introducing TBP at the primary level is feasible, provided it takes place within an environment that preserves continuity in representations and practices.

With respect to the second research question, the results indicate that emotional changes during language transitions depend less on the programming language itself than on the context in which the transition occurs, including whether it is imposed or initiated by the student and the pedagogical moment at which it takes place. Transitions toward TBP imposed by the instructional sequence, when grounded in a solution that is already understood or validated, are generally associated with positive or stable emotions, suggesting that the shift to TBP can be emotionally sustainable when pedagogically prepared. Conversely, when such transitions are imposed while difficulties remain unresolved, they may lead to temporary emotional disorganization, reflecting a break in the activity flow rather than rejection of TBP. Back-and-forth transitions between the two languages reflect exploratory and comparative

strategies. When initiated by students outside blocking situations, these transitions are accompanied by emotional stability, indicating functional and complementary use of both representations. However, when transitions follow unsuccessful execution attempts, repeated switching may lead to dispersion, revealing persistent cognitive uncertainty that requires targeted pedagogical support. Finally, transitions back to BBP emerge as key moments of emotional regulation, allowing students to return to a more familiar representation to reconstruct their reasoning and regain control of the activity.

Overall, these findings position BBP–TBP transitions as orchestratable design parameters in hybrid environments, where timing and framing shape emotional regulation and engagement.

7. Conclusion

The results of this exploratory study show that hybrid programming environments, identified in the literature as relevant intermediaries to support the transition between BBP and TBP (Lin & Weintrop, 2021), also provide a favorable framework for an emotionally sustainable transition between these two modalities. Contrary to views framing this transition as intrinsically emotionally costly, the findings suggest that, within a hybrid environment, the transition toward TBP can unfold with emotional continuity for most students.

The value of such environments lies less in the mere coexistence of two programming languages than in the possibility of flexible, contextualized, and pedagogically orchestrated transitions between them. The results indicate that several parameters play a decisive role in students' emotional experience, including the timing of the transition, whether it is imposed or voluntary, and its grounding in task understanding.

These elements can be considered as pedagogical design parameters for orchestrating BBP–TBP transitions. In this sense, the study contributes to research calling for the development of intermediate environments to support language transitions by integrating an emotional dimension that remains underexplored. It invites educators and researchers to conceive transitions not as simple technical operations but as pedagogical moments, requiring careful orchestration to support students' engagement, conceptual understanding, and emotional regulation during programming learning.

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