

VU Research Portal

DRAFT-What you always wanted to know but could not find about block-based environments

Merino, Mauricio Verano; Vinju, Jurgen; Brand, Mark van den

2021

DOI (link to publisher)

<https://arxiv.org/abs/2110.03073>

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Merino, M. V., Vinju, J., & Brand, M. V. D. (2021). *DRAFT-What you always wanted to know but could not find about block-based environments*. <https://doi.org/https://arxiv.org/abs/2110.03073>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

DRAFT-What you always wanted to know but could not find about block-based environments

MAURICIO VERANO MERINO*, Eindhoven University of Technology - CWI, The Netherlands

JURGEN VINJU, CWI - Eindhoven University of Technology, The Netherlands

MARK VAN DEN BRAND, Eindhoven University of Technology, The Netherlands

Block-based environments are visual programming environments, which are becoming more and more popular because of their ease of use. The ease of use comes thanks to their intuitive graphical representation and structural metaphors (jigsaw-like puzzles) to display valid combinations of language constructs to the users. Part of the current popularity of block-based environments is thanks to Scratch. As a result they are often associated with tools for children or young learners. However, it is unclear how these types of programming environments are developed and used in general. So we conducted a systematic literature review on block-based environments by studying 152 papers published between 2014 and 2020, and a non-systematic tool review of 32 block-based environments. In particular, we provide a helpful inventory of block-based editors for end-users on different topics and domains. Likewise, we focused on identifying the main components of block-based environments, how they are engineered, and how they are used. This survey should be equally helpful for language engineering researchers and language engineers alike.

CCS Concepts: • **General and reference** → **Surveys and overviews**; • **Software and its engineering** → **Graphical user interface languages**; **Visual languages**; *Integrated and visual development environments*.

Additional Key Words and Phrases: block-based environments, visual languages, programming environments, language engineering

ACM Reference Format:

Mauricio Verano Merino, Jurgen Vinju, and Mark van den Brand. 2021. DRAFT-What you always wanted to know but could not find about block-based environments. *ACM Comput. Surv.* 1, 1 (October 2021), 43 pages. <https://doi.org/10.1145/nnnnnnnn.nnnnnnn>

1 INTRODUCTION

In the past decade, end-user programming environments have become more popular and more relevant. End-users significantly outnumber professional programmers [127]. These environments allow end-users to create and adapt software, enabling them to achieve a myriad of tasks. Without them, most of these tasks would not be possible unless one has a background in computer science or software engineering. Block-based environments are part of this set of end-user visual programming environments. One of their main characteristics is the editor, which presents the language constructs to the end-user as graphical elements that resemble Lego blocks. Each of these blocks is characterized by visual signifiers (e.g., color and shape) that hint end-users of its semantics and its (possible) connections to other blocks. An example of a block-based representation of an `if` statement is shown in Figure 1. The benefit of having a block-based

Authors' addresses: Mauricio Verano Merino, m.verano.merino@tue.nl, Eindhoven University of Technology - CWI, Eindhoven, The Netherlands; Jurgen Vinju, CWI - Eindhoven University of Technology, Amsterdam, The Netherlands, Jurgen.Vinju@cwi.nl; Mark van den Brand, Eindhoven University of Technology, Eindhoven, The Netherlands, M.G.J.v.d.Brand@tue.nl.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

© 2021 Association for Computing Machinery.

Manuscript submitted to ACM

Manuscript submitted to ACM

editor is to offer a programming experience based on what-you-see-is-what-you-get (WYSIWYG) and the impossibility of syntactic errors [105, 118, 168, 170]. Moreover, these editors support different block-based programming paradigms, such as *configuration*, *serial*, *parallel*, and *event-driven* [57].



Fig. 1. Block-based representation of an if statement.

The popularity of block-based editors have increased in recent years, partially due to Scratch’s popularity (23rd most popular programming language [27]). However, languages that provide such a type of editors are not new, yet block-based editors have been mainly used and associated with computer science education or applications for children. This paper explores whether this is true or not. In case this claim is not true, we explore how these programming environments have been adopted beyond the realms of education or children. Moreover, this paper identifies block-based environments’ main components to understand them and increase their adoption in different domains and for different user groups; and studies whether the development of block-based environments is supported by specialized language engineering tooling (e.g., language workbenches).

To have a clear overview of the landscape of block-based environments and understand how they are developed, we conducted a systematic and a less-systematic literature review. A systematic literature review collects and summarizes all the existing research evidence of a domain and identifies possible gaps in current research [79]. Initially we started with the less-systematic method, in which we sought block-based environments and their features. We ran into the limits of this ad-hoc method and continued with an SLR (structured literature review) to identify possible gaps in current research [79].

Since there exists no primary conference or journal focused on block-based environments, we expect that papers on this topic are spread over different academic communities with different characteristics. The papers we found in the venues will frame the answers to the research questions about block-based environments.

The contributions of this paper are summarized as follows:

- A systematic literature review on block-based environments which provides an overview of the main features of block-based environments, the landscape in which these programming environments are used, publication venues, programming languages used in their development, and the most popular environments (Section 3).
- A deeper (qualitative) understanding of block-based environments and their components (Section 3.2).
- An understanding of how block-based environments are implemented and the tools and languages involved in their development (Sections 3.4 and 3.5).
- A non-systematic tool review of block-based environments that presents some of the most relevant features of these programming environments (Section 4).

We describe the threats to the validity of this study in Section 5 and a discussion of the results obtained in this study in Section 6. The non-systematic literature review fills some gaps of the systematic literature review and vice versa. We concludes with a discussion of related work, conclusions and future research directions (Sections 7 and 8).

2 SYSTEMATIC REVIEW: MOTIVATION AND METHODOLOGY

A literature review about block-based environments can be approached from different perspectives. Different perspectives are relevant because block-based environments are used across different domains and user groups, and developed by engineers with different backgrounds as well. Our agenda is to make block-based editors part of the default set of services offered by language workbenches [51] and to investigate how editor generation technology (metaprogramming) is used to support this. Therefore, our primary motivation in this literature review is to understand in which contexts are block-based environments used and how exactly they are developed.

We aim to make block-based environments available for all DSLs developed using a language workbench (LWB). LWBs have shown benefits by offering specialized (generative) technology for developing software languages and their tooling. LWBs are used to define both the syntax and semantics of languages. Based on these two, language engineers can also semi-automatically derive a full-featured IDE for their language [24, 30, 157]. We believe that block-based editors can also be derived from existing language components. To enable that research we need a clear set of requirements to frame the contributions of a block-based LWB and we must understand how block-based environments are best implemented. The current SLR helps in achieving these goals.

2.1 Need for a systematic review

Coronado et al. [33] published a literature review about using visual programming environments for programming robots. In their work, they present an overview of the environments that use a visual editor for programming robots; this considers all sorts of graphical elements to represent language constructs, including block-based editors. However, their main target was to understand the tools used to program robots. A similar approach can be used for other purposes, for instance, to identify the programming environments used for teaching computational skills. Our view is that it is essential to understand block-based environments in general; this includes understanding their features, applications, and technologies involved in their development.

We aim to increase the adoption of the block-based metaphor beyond the realm of computing education, make its development part of the set of generic services offered by specialized tooling for creating software languages (i.e., language workbenches), and explore further applications in industrial settings.

2.2 Protocol

This section presents the protocol defined for the systematic review. We followed Kitchenham et al. [78, 79] guidelines for conducting a systematic literature review in software engineering. The primary goal is to summarize existing evidence in literature of the development and usage of block-based environments, in different disciplines. The secondary goal is to identify possible gaps between the development of these visual programming environments and existing tools and technologies specialized in developing software languages and their tooling.

2.2.1 Scope. Visual programming environments are environments that rely on graphical editors for building programs. Different notations are adopted by these environments, such as flow charts, UML diagrams, and block-based editors. In this survey, we focus our attention on the latter notation.

Block-based environments are not new, but the popularity of Scratch¹ has inspired a new wave of visual programming environments. These environments are characterized by representing language constructs with graphical blocks

¹<https://scratch.mit.edu/>

that resemble Lego blocks. Moreover, these environments offer visual cues that help users understand what are the possibilities for connecting blocks.

2.2.2 *Research questions.* The research questions addressed in this study are:

RQ0 *What are the characteristics of the papers that present block-based editors?*

RQ1 *What are the components of a block-based environment?*

RQ2 *What are the tools used to develop block-based environments?*

RQ3 *How are block-based environments developed?*

RQ4 *What languages offer a block-based editor and what are these languages used for?*

The motivation for the meta question **RQ0** is that we expect publications on block-based editors to be scattered across many different (types of) venues: from fundamental computer science all the way to applications in other academic domains such as medicine, and everything in between. The answer to **RQ0** helps to frame the answers to the following research questions. Research questions **RQ0**, **RQ2**, and **RQ3** are answered through the systematic review. **RQ1** and **RQ4** are answered using both the systematic and the non-systematic approach.

2.3 Search process

Languages that use a block-based editor are becoming popular outside the academic world for their ease of use. For instance, commercial robots, programmable microcontrollers, and applications for children use them as an effective end-user interface. Consequently, many of these languages have been developed outside the academic world, which means that there are language implementations that do not have a corresponding academic publication. Vice versa there exist academic publications about languages which do not have an implementation (anymore).

Therefore, to obtain a complete overview of the landscape, it is essential to include both academic and non-academic tools in this literature review. Therefore, we decided to follow a combined search process that is both fully systematic and less-systematic. For the fully systematic process, the first author systematically searched for peer-reviewed papers in computer science academic databases. The less-systematic process was conducted using standard Google search queries. In some cases, some tools reference other tools, so we also used this information. Following this approach, we found 30 different relevant block-based environments.

We consider using Google scholar for the systematic approach, but unfortunately, it provided more than 2.6k results, which is more than what we can deal with. Therefore, we reduced the search space to the four primary academic databases in computer science and software engineering, namely, IEEE, ACM, Elsevier, and Springerlink. The selected academic databases are shown in Table 1. They were selected because these databases are well known, and they have proceedings of the leading journals and conferences on which block-based environments have been applied, such as education, software engineering, human-computer interaction, and end-user programming.

2.4 Queries

To identify and understand languages that offer block-based editors, we used the following *search string* in the academic databases:

block-based language OR blocks-based language OR block-based languages OR blocks-based languages
OR block-based programming OR blocks-based programming

We used the search string mentioned above for all four academic databases. A summary of the number of results obtained from each database is presented in Table 1. Table 2 presents a summary of the type and number of publications obtained across all the databases. The publication type *Other* aggregates different types of publications such as demonstrations, posters, magazine columns, tutorials, outlines, living reference work entries, panels, conference description, editorials, and non-peer-reviewed technical reports. Details about the inclusion or exclusion criteria for the relevant proceedings are explained below in Section 2.5.

Source	# Results
IEEE Xplore ®Digital Library	128
The ACM Digital Library	272
Elsevier ScienceDirect ®	55
Springerlink ®	213
Total	668

Table 1. Number of publications obtained per academic database.

Publication type	# Papers
Conference paper	369
Journal	143
Other	50
Chapter	44
Abstract	40
Short paper	22

Table 2. Number of publications per type.

2.5 Inclusion and Exclusion Criteria

This section presents the criteria we used for both the systematic and the less-systematic approach.

Non-academic. We included solely tools that can be used at the moment of the systematic review, (i) Open-source tools. (ii) Commercial tools with free trial. This includes languages and tools that can be accessed only by contacting the authors, as described on the tool’s website.

Academic. We reviewed the title and abstract of each paper manually to remove all papers that certainly were not featuring languages with block-based environments. The proceedings used in this literature review are all peer-reviewed articles related to block-based programming in the broad sense, published between January 1st, 2005 and August 1st, 2020. Note that we are interested in all articles related to block-based interfaces, so we included all articles that used or mentioned block-based languages or block-based programming even if they present applications or studies of the block-based metaphor solely.

We excluded articles on the following topics: (i) Visual languages that do not feature a block-based editor (ii) Studies not written in English (iii) Frame-based editing unless they provide a connection to block-based editors (iv) Data-flow programming (v) Form-filling programming (vi) Wizardry metaphor [45] (vii) Duplicate articles that present the same tool without adding a fresh perspective.

Finally, we excluded reference work entries, living reference work entries, and educational papers unless they introduce a new tool, a language, or an extension to an existing tool or language that uses a block-based editor.

2.6 Selection

To identify the relevant publications to be included as part of this SLR, we performed three-step filtering (Figure 2) on the results obtained from all the databases using the string query mentioned before. We took each result in the first filtering phase and we evaluated its relevance based on the title and the abstract only. Only papers that include something about block-based environments were kept. For each excluded paper, we wrote a motivation about why it was discarded. After this process, the number of papers was reduced from 668 to 423. After removing 11 accidental

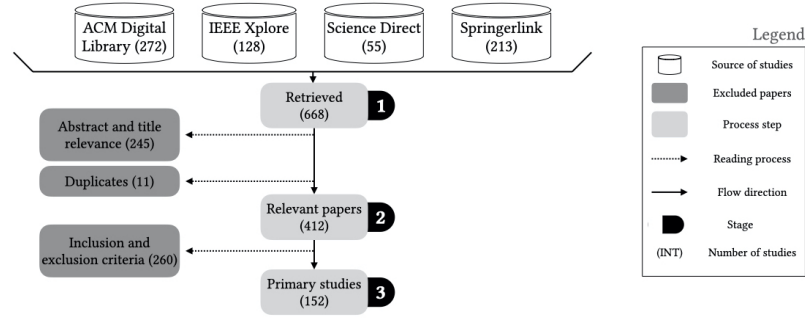


Fig. 2. Selection procedure for the systematic literature review.

duplicates we ended up with 412 papers. The second filter step starts with all the papers that resulted from the first filter. In this phase we defined nine yes/no questions based on our research questions. The nine questions are shown in Appendix A. Then we counted the number of yes answers for each individual paper. Based on this count we chose a threshold to include a paper for the subsequent filtering step.

Since answering the nine questions is a manual task, the second author double-checked a random selection of ten papers by following the exact same protocol. We measured the degree of agreement between both authors and we calculated *Cohen's kappa* coefficient [32]. This statistic is used to measure the degree of accuracy and reliability in statistical classification. Both authors agreed to include five papers and exclude four papers. However, the first author decided to include one paper that the second did not. To quantify this: there was 90% agreement between the authors and Cohen's kappa was 0.8. According to the guidelines proposed by Landis and Koch [89], a 0.8 Cohen's coefficient means that there is a *substantial agreement* between the parties.

This literature review's primary focus is to provide a landscape of languages and tools related to block-based environments. Therefore, the main criteria to include a paper is to introduce a language or a tool that uses a block-based environment. If that is the case, the paper is included even if the number of yes answers is not greater than the threshold. If the paper does not include a language or a tool, we use the accumulated result to determine whether the paper is included. Thus, a paper that does not introduce a tool or a language must have more than four positive answers. As we did in the first filtering phase, we always record why a paper is discarded.

The second filter's resulting papers are then the ones on which the current survey is based; this means those are the papers from which we extract the data for further processing and discussion. As a result of the second filtering phase, we excluded 260 papers from the 412 we had after the first filtering. As a result we analyzed 152 papers in the data extraction phase. During data extraction, we retrieved different elements, such as the type of publication, details about the block-based environment (e.g., elements of the editor and its position on the screen), and all kinds of editor implementation details. All the data was collected in a spreadsheet and its content was then analyzed and processed by different means using scripts that aggregate the raw data. The result of this process is shown and explained in the following sections.

3 SYSTEMATIC REVIEW OF BLOCK-BASED ENVIRONMENTS

In this section we answer the research questions (Section 2) using the data collected from the 152 papers on block-based editors.

3.1 RQ0: What are the characteristics of the papers that present block-based editors?

This section presents demographics of the papers included in this survey. Particularly, we present the venues in which the included papers were published, the number of papers included per year, and the number of papers per country. Table 3 presents a summary of the venues that contributed the most number of papers. For readability we present only the categories that contain venues that contributed at least two papers. The complete list of categories and venues is listed in Appendix C.

Category	Venue	# Papers
Human computer interaction	Conference on Human Factors in Computing Systems (CHI)	13
	Conference on Interaction Design and Children	11
	International Conference on Human-Computer Interaction (HCII)	4
	International Journal of Child-Computer Interaction	3
Programming / Human computer Interaction	Blocks and Beyond Workshop (Blocks and Beyond)	13
	Symposium on Visual Languages and Human-Centric Computing (VL/HCC)	9
	Journal of Visual Languages & Computing	2
	International Symposium on End User Development (IS-EUD)	2
Education	Technical Symposium on Computer Science Education (SIGSE)	10
	Global Engineering Education Conference (EDUCON)	5
	Computational Thinking Education	2
	Education and Information Technologies	2
	Workshop in Primary and Secondary Computing Education	2
	International Conference on International Computing Education Research	2
Distributed computing	Conference on International Computing Education Research	2
	International Conference on Computing, Communication and Networking Technologies	5
Robotics / Education	International Conference on Robotics and Education (RiE)	4
Accessibility	Conference on Computers and Accessibility (ASSETS)	2
Programming	Science of Computer Programming	2
Security	International Conference on Information Systems Security and Privacy (ICISSP)	2
Software engineering	International Working Conference on Source Code Analysis and Manipulation (SCAM)	2

Table 3. Summary of venues that contributed at least two papers to the survey.

To get a quick overview of the most important venues we ordered them in Table 3 by ranking them by “popularity”. Moreover, we manually classified them into 18 categories. For the classification process we tried two semi-automated alternatives using a more systematic approach, namely (a) calculating the document distance between calls-for-papers of each venues and (b) using Google’s Cloud Natural Language API ² to classify each call-for-papers. The bottom-line is that both approaches did not produce accurate results and so we went back to the manual classification. We report on these negative results nevertheless, as they might be useful to others researchers that are working on an SLR.

We extracted the text in the call for papers of a random sample of venues to use these to test the two automated approaches. In this step, we notice that not all venues present a clear list of topics (e.g. the ACM CHI conference). For the first approach, we calculated the document distance between two calls for papers from the same field. By manually verifying documents which were either far apart, or close, with our own understanding we noticed nothing but noisy results. Apparently the variety of topics in calls for papers goes far beyond the variety of topics of what a conference is about.

To explore this further, we removed all the other text from the call from papers, and we calculated the document distances based only on the research topics mentioned in the call for papers. However, this did not improve the results,

²<https://cloud.google.com/natural-language>

and the document distance between two venues from the same field was not too close (false negatives). And, in many cases even, comparing venues from distinct fields produced closer distances (false positives).

The second approach used the same input data. We used the default Google’s classification categories on the same texts, and the results were indeed accurate (correct), but they were not precise enough (vague). I.e. most of the venues were classified as “computer science”.

After these failed attempts to automate and objectify our classification, we continued with a manual classification process. Table 3 shows that the venues that contributed the highest amount of papers are CHI and ‘Blocks and beyond’, with 13 papers each. The former is a venue about human factors in computing systems, including interaction, visualization, and human-computer interaction topics. Thus, it is a clear connection between these topics and the benefits offered by block-based environments. The latter venue is exclusively focused on the development and use of block-based environments. Therefore it is a perfect match for the study we present in this survey.

The papers included in this study are from different domains such as Human-Computer Interaction (HCI), Education, Design, Software Engineering, Robotics, and Security. Based on all the venues that contributed at least one paper, we expect our paper collection process to be rather complete for this study since we have publications from a variety of heterogeneous sources and topics. Likewise, this study includes different types of proceedings as shown in Table 2.

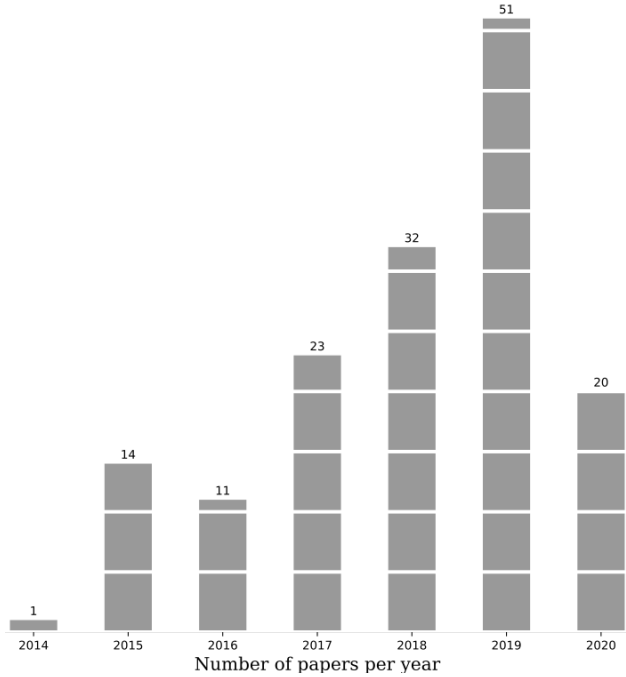


Table 4. Summary of the number of papers published per year.

Publication Type	# Papers
Study	31
Languages	95
Extension	27

Table 5. Summary of the number of papers included in this study per type of proceeding

To understand the papers’ demography, we computed the number of papers that we included in our study per year, as shown in Table 4. This figure shows that the number of papers per year has increased, having its peak in 2019. It is important to remark that the current survey’s search process solely included papers published before August 1st,

2020. This probably explains why the number of papers in 2020 is lower than in 2019. With Table 4, we can observe an increase in popularity on topics related to block-based environments.

Moreover, we computed the number of papers published per country. To compute this information we used the nationality of the first author as presented in the paper, and then we calculated the number of occurrences per country. We can observe that the United States is the country that contributed the highest number of papers, followed by the United Kingdom with 64 and 14 papers, respectively. It is essential to mention that the gap between the number of papers contributed by the US is more than four times the number of UK papers. It is also interesting to observe that we have some degree of diversity in the authors' nationality; there are authors from different continents —North America, South America, Europe, and Asia. Antarctica, Africa, and Australia are not represented. The complete list of papers per country is presented in Appendix D.

While analyzing the papers, we decided to tag them using three categories *study*, *language*, and *extension*. We defined these categories to classify the papers based on their content. The first category, *study*, is used to group papers that study aspects of using or implementing block-based environments and do not present a new language or tool that uses the block-based metaphor. The *languages* category is used to group all the papers that present a new language that includes a block-based editor or tools that support the development of block-based environments. Finally, the *extension* category groups papers that do not introduce a language but introduce new features to existing block-based editors. Table 5 presents a summary of the number of papers per category.

Based on the previous information, the reader can observe that the included papers come from a wide range of topics, types of publications, and authors from different parts of the world. In the next section, we will present in more detail findings and information that we obtained by analyzing and gathering data from the corpus of papers, and that helps us answer the research questions defined in Section 2.2.2.

Summary RQ0

- Publication of block-based environments is spread among different communities, however they are most present in education, human computer interaction, and programming venues.
- The number of publications that present block-based editors have been increasing since 2014. This is supported by the importance of programming in the last years among different people, including students and non-professional programmers.
- Authors from many countries publish papers that use block-based environment. However, the country that contributes the most number of papers to this study is the United States, followed by the UK.
- In this survey, we classified the 152 papers based on their goal in three main categories, studies, languages, or extensions. Most of the papers included in this study are papers that introduce a language (95), followed by studies of the usage of block-based editors (31) and, finally, papers that introduce extensions to existing block-based environments (27).

3.2 RQ1: What are the components of a block-based environment?

This section addresses research question **RQ1** based on the data collected. For this purpose, we used the papers' classification from the previous section and we took the ones from the *languages* group. From the total number of papers we considered a subset of 95 papers (Table 5).

Based on the different features offered from all the block-based environments in this study, we developed a feature diagram [73] that summarizes the most common features found across different platforms. The complete set of features of block-based environments is shown in Figures 3 and 4. To ease the diagram's readability, we split the *editor* feature into a separate diagram, as shown in Figure 4. Figure 3 shows the first part of the diagram. Here the reader can

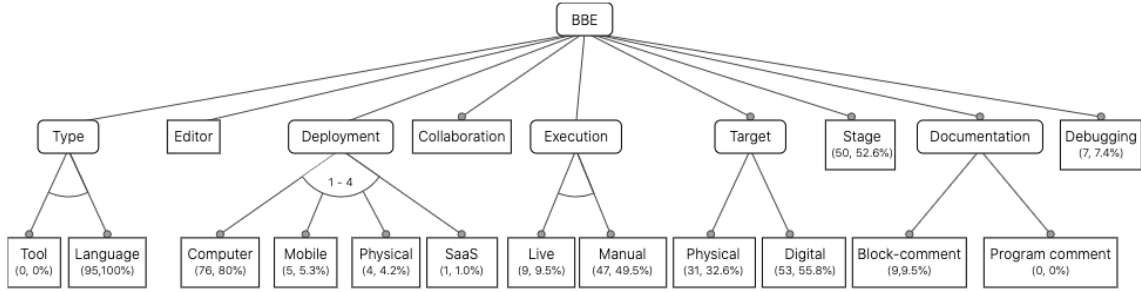


Fig. 3. This is the top-level of the feature diagram.

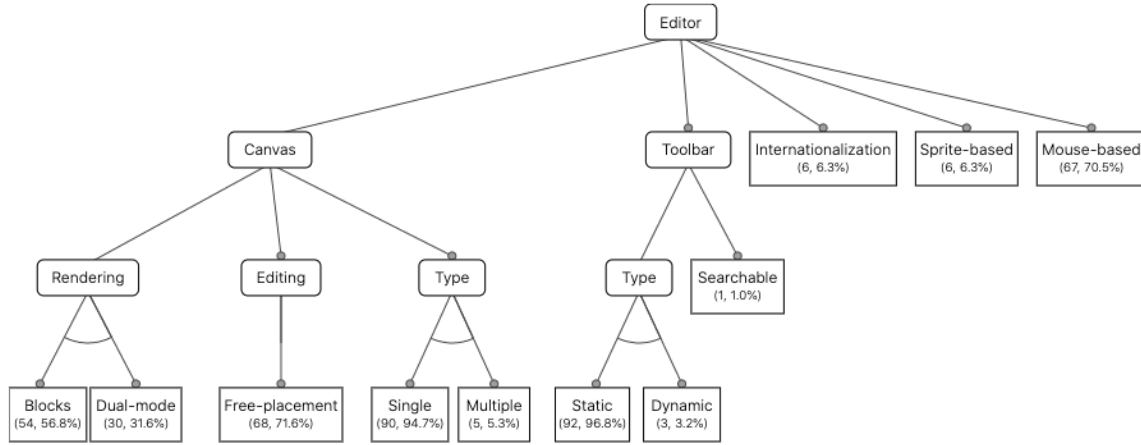


Fig. 4. This feature diagram shows a zoom-in into the editor aspect of a BBE.

observe features related to the functioning of the platform. For instance, *licensing*, *code execution mode*, and the *type* of block-based environment. Then, Figure 4 presents details of the block-based editor.

In the feature model, we used two types of features, mandatory and optional. The first is used for standard features (depicted as a box in Figures 3 and 4), and the latter for unique features (depicted as a box with a blank circle on top). The root node in Figure 3 represents a block-based environment, and each of the leaf nodes in the feature diagram displays the number of block-based environments that support that feature and the percentage of tools that support it among all the papers. For instance, *Computer* (76, 80%) means that 76 block-based environments are deployed for computers, which is 80% of the papers used for creating this diagram. All the block-based environment's children nodes are described below.

Type. There are mainly two types of block-based environments, *tools*, and *languages*. The former refers to utilities that help the development of such environments. Instead, the latter are languages that come with a block-based editor.

Editor. Block-based environments provide a block-based editor, but, we identified that some tools also support a hybrid editor (text and blocks), which means that it is possible to interact with the underlying language either through a blocks editor or text-based editor. Based on this, 69 of the studied tools support a block editor only, while 15

support both blocks and text editor [6, 7, 12, 15, 18, 20, 22, 34, 40, 62, 76, 77, 90, 143, 164]. The remaining ten tools do not mention it at all.

Deployment. A block-based environment can be used through a heterogeneous set of devices (e.g., laptops, tablets, and wearables). Therefore, we investigated what device do block-based environment users write or develop their programs with. The majority of tools are used through a browser-enabled PC (76), five through mobile devices (e.g., smartphones), four by manipulating physical elements, and one as Software as a Service (SaaS). In nine of the tools, it was not clear which type of device the users have to develop their programs.

Collaborative. This feature represents whether a block-based environment supports mechanisms for users to collaborate in the development of programs. From the studied papers, 90 tools do not offer such capabilities. Instead, the remaining five tools do support this feature.

Execution. There are different ways of executing programs. This is not different in a block-based environment. Based on this study, we identified mainly two execution modes, *manual* and *live*. After finishing the development of their programs, a manual execution means that users have to press a button to launch the execution of the program by the underlying language processors. Instead, a *live* execution mode does not require a manual intervention by the user to execute programs. The platform is capable of live executing the programs as users develop them. From the tools, 47 use a manual execution mechanism, nine use a live execution, and the remaining 39 tools do not mention which execution mode do they use.

Target. As mentioned before, block-based environments are used in different settings. This includes the real and the digital world. Thus, sometimes the effects of running a block-based program are displayed on the screen, but sometimes they are shown via hardware, and sometimes both. We investigated this fact and found that 53 tools present some form of results in a digital way, 31 using hardware (physical), and three using both. For the remaining eight tools, it is not clear from the papers which one do they use.

Stage. Block-based editors are used in different environments. In some environments, the effects of running a program are represented in the real world (e.g., hardware effects). However, other contexts in which the results are displayed as software (e.g., animation). This feature characterizes if the block-based environment has a dedicated pane for showing the effects of running a program. Of the 95 tools, 50 of them have a dedicated pane for rendering program results; the remaining 45 do not have such a pane. Since there is no standard way or location for placing a stage, we investigated the most common place in which block-based environment developers place this component. The preferred location for the canvas is the right-most side of the screen, with 22 tools. Then, 19 tools place it to the left-most part of the screen. Two tools place it in the center; similarly, two tools have it in the bottom part. Finally, only one tool has the stage on the top part of the screen.

However, the following four tools do have a stage, but the paper is not clear wherein the screen it is located. Below, we present the details for these four tools. Catrobat [108] uses a different layout because it is a mobile app. Behavioral Blockly [9] does not show the whole block-based environment. Some images show the programs, and others that show the stage, but not the whole workspace. In VEDILS [107] there are different screens for showing the stage and editing the program. For the mBlock [92] tool it is not clear where the stage is located from the paper's screenshots.

Documentation. Documentation is an essential aspect of software. In traditional text-based programming environments, it is possible to add comments anywhere in the program as long as it does not introduce syntactic errors. In a block-based environment, this is more restricted due to the projectional nature and the visual components.

Therefore, we identified mainly two types of documentation. One is used to add documentation to specific blocks (*block-comments*), and the other documents a complete program/script (*program comments*).

Block-comments As introduced before, block-comments are the comments added to specific blocks. This could be either a group of blocks stacked up together or a single block. From the studied papers, nine tools allow users to add comments per block, while the other 86 tools did not mention it explicitly.

Program comments. This feature is presented to show whether the tools allow users to add comments to complete scripts/programs. We found that none of the tools found in this study support adding comments to block-based programs.

Debugging. Traditional software development tools support the debugging of programs. This is no different for block-based environments; however, we found that not all block-based environments support debugging features. From all the tools, only seven tools come with debugging features. The remaining 87 do not mention it; we assume they do not offer such capabilities.

Next, we present in detail the features that are part of the block-based editor Figure 4.

Canvas. The canvas is where users create their programs; it is where they drop the blocks that constitute programs. All block-based environments offer a canvas for building the programs. Most of the papers (70) show their canvases, but some (24) papers did not present screenshots that show the canvas explicitly. Some of these publications that did not present the canvas present block-based programs. The canvas location indicates wherein the screen is this component situated. For 49 of the tools, the canvas is located in the center of the window; 16 have it on the right-most part; one in the left-most part of the screen, and one have it in the bottom part. As explained before, the remaining 27 tools do not mention or display their position.

Canvas type. Some environments provide more than a single canvas for creating programs. Therefore, we look at the papers, and we found that five tools do use multiple canvases, and the remaining 90 either only offer a single canvas or do not explicitly mention/show support for multiple canvases.

Rendering. This feature means that the block-based environment displays programs using only blocks or dual-mode (text and blocks). 54 of the block-based environments display programs using only a block-based representation, 30 tools support a dual-mode, and the remaining 11 tools do not mention anything about it.

Editing. A canvas allows users to build programs by placing blocks on it. However, this does not mean that all block-based editors use a 2D space. From all the tools, the majority supports the free placement of blocks in a two-dimensional space. However, the other 27 tools have other types of placement (e.g., 3D spaces or non-free placement of blocks).

Toolbar. The toolbar is where blocks are grouped so that users can look at what language constructs (blocks) are available for further use. Sixty-seven languages have a block-based editor that contains a palette, and 27 do not provide it or it is not explicitly mentioned. Moreover, we analyzed the location of the palette also from the papers. There are four possible locations *top*, *bottom*, *left*, or *right*. We found that 47 tools have the palette on the left-most part of the window. This might be related that the majority of the people read from left to right. Moreover, four tools (*Flip* [56], *Labenah* [3], [93], and *Tuk tuk* [84]) have the palette in the right-most part of the screen. Twelve tools have it in the middle of the screen; this behavior usually presents a stage on one side and the editor on the opposite side. In this way, the palette is in the middle. Finally, *XLBlocks* [69] displays the toolbox at the top of the window and *Tica* [4] does it in the bottom part.

Toolbar Type. A palette usually groups blocks by categories and this grouping is *static*, meaning users can inspect each category and its blocks, and it will not change. However, we identified that some tools offer a *dynamic* toolbar. A dynamic toolbar is a toolbar that automatically adapts its contents based on the program’s current status. In other words, it automatically hides the blocks that cannot be snap into the current status of the program. There are 91 tools that do not support this feature, but *EduBot* [67], *PRIME* [123], and *EUD-MARS* [2] do.

Searchable Toolbar. A *searchable palette* is a palette that has a search bar to help users find blocks without having to open each category. *EduBot* [67] is the only tool that supports a searchable toolbar.

Internationalization. Given the visual notion of a block-based environment and the possibility of adding descriptions to language constructs in natural language, we investigated if the block-based tools come with support for different languages, which means, if the description of a block can be shown in several languages (e.g., English, Spanish, Dutch). We found that only six tools come with internationalization capabilities, and the vast majority (89) do not support it.

Sprite-based. Sprites are graphic elements of a computer program that can be manipulated as single units. This concept is popular among block-based environment because Scratch supports it. However, we found that is not true for all languages that offer a block-based editor. We identified six tools that support first-class sprites, while the remaining 89 do not.

Mouse-based manipulation. This feature is to reflect how users can manipulate blocks within a block-based environment. Sixty-seven tools support the direct manipulation of blocks using the mouse, while the other 28 tools have different manipulation mechanisms (e.g., physical manipulation).

Summary RQ1

- The feature diagram (Figures 3 and 4) displays the most important features across block-based environments. There are features at two different levels, *platform*, and *editor*. At the *platform* level, we find features such as documentation, collaborative support, deployment, and stage. The *editor*-level features are the canvas, toolbar, internationalization, and sprite-based editing. Based on our data, we present quantitative analysis to illustrate which tools support each feature. Likewise, we also illustrate the position in which some of these features appear in a block-based environment (e.g., canvas, toolbar, and stage location).
- We identified that –due to the diverse applications in which these environments are used– a standardized set of block-based editor features is missing. Therefore, we propose a feature diagram that summarizes them across different platforms. Notably, we identified two main types of features: platform-based and editor-based.
- We identified that most block-based environments provide a palette that contains all the language construct and a canvas, in which users develop their programs. The stage is a key component in popular platforms, however, their presence varies depending on the language’s goal.
- There are two main types of block-based editors: sprite-based (e.g., Scratch) and non-sprite-based.

3.3 RQ2: What are the tools used to develop block-based environments?

We want to learn how block-based environments are developed. However, given the nature of the papers, this is a non-trivial activity because in most cases we noticed that authors do not mention these details. Below, we present the data we extracted. Depending on how the language was implemented, we classified each paper into one of four categories General-Purpose Programming Language (GPL), grammar, DSL, and not available (N/A). As shown in Table 6, 93 tools did not explicitly mention the tools used for its development, 55 were implemented using a GPL, and from the remaining three: one used a visual language, one used a grammar, and one used a DSL, respectively.

Likewise, we studied what programming languages were used in the implementation of these block-based environments. Table 7 presents a summary of our findings. For conciseness we grouped some of the languages (for the full

list see Appendix F). For instance, some languages only mention the use of HTML, so we count it as part of *HTML*, *JavaScript*, and *CSS*.

Category	# Languages
N/A	93
GPL	55
DSL	1
Visual (blocks)	1
Grammar	1

Table 6. Language selection for the development of block-based environments.

Programming language	Papers
N/A	100
JavaScript	15
HTML, JavaScript, and CSS	15
Java	3
Python	2
iOS (Swift)	2
JavaScript & Java	2
Pharo Smalltalk	2
TypeScript	2

Table 7. Programming languages used to implement block-based environments.

As mentioned before, implementation details are not always discussed, and this is reflected in Table 7; 100 papers do not mention what programming language was used for the development. After this, we see that the most popular programming language for the development of block-based environments is JavaScript. Counting all the appearances, this language was used in the development of more than 30 block-based editors. Another interesting fact is that there is only one language developed using a Language Workbench (JastAdd [150]).

Following this direction, we explored whether the papers did not mention programming languages at all, or it was just that they did not present implementation details of their tooling. We used the list of the 50 most popular languages as reported by the TIOBE index [27], but “visual basic” was omitted from the search because of the many false positives with the common words “visual” and “basic”. In fact we did not find any block-based editor that was implemented in Visual Basic.

Based on the list of programming languages, we developed a tool ³ for mining the corpus of PDF files and counting the occurrences of each programming language. The results in Figure 5 show the popularity of each of programming language. The complete list of details of each language and the number of papers that mention the language is presented in Appendix F.

As shown in Figure 5, Scratch is by far the language most mentioned across the papers. The reason for this is that most of the current block-based environments took inspiration from it. Then, we found seven programming languages (C, Java, Go, R, JavaScript, D, and Python) mentioned in more than 20% of the papers. These languages’ popularity might be related to the technologies used to develop block-based environments, and the libraries offered to support their development (e.g., Blockly).

In summary, we identified that most of the papers do not present implementation details about their languages and editors. However, based on the papers that present implementation details, we found that most of the authors use GPLs. Concretely, most of the papers that presented such details used HTML, JavaScript, and CSS to implement block-based environments. Likewise, we observed that the programming languages used to develop block-based editors are aligned with the 50 most popular languages as classified in the TIOBE index.

³<https://github.com/maveme/PDFMiner>

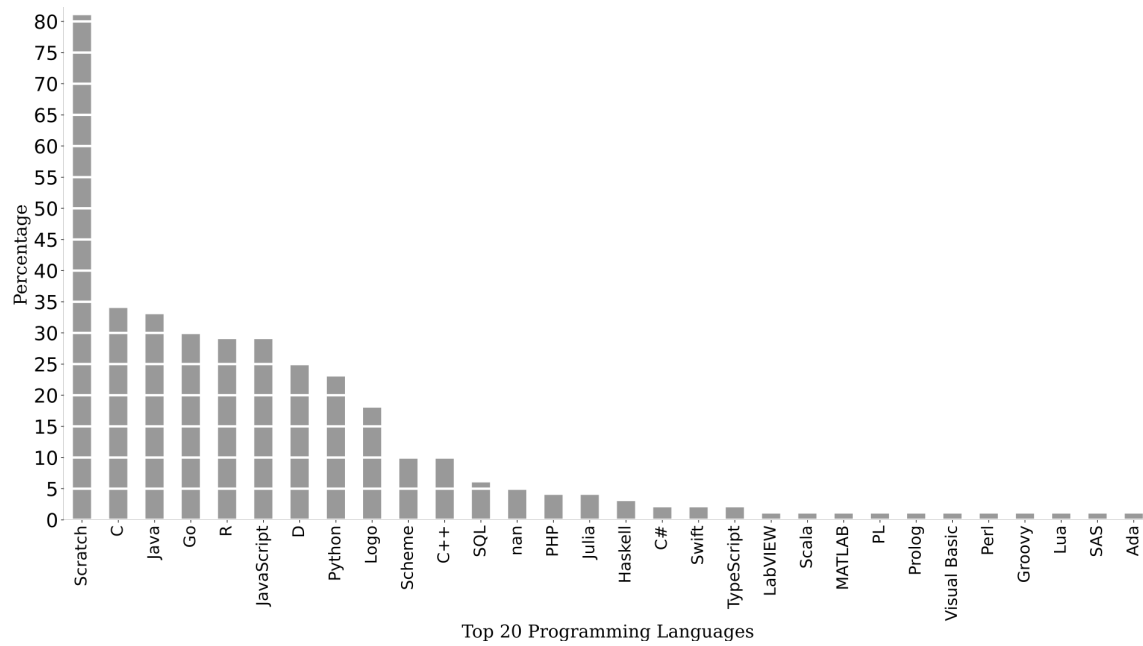


Fig. 5. Summary of programming languages used for implementing block-based environments.

Summary RQ2

- We identified different ways in which block-based environment are developed. However, most of the authors (93) did not include such details. The most popular way of developing a block-based environment is employing a general-purpose programming language (GPL).
- Since using a GPL is the most common way of developing block-based environment, we identified that the most popular languages for this endeavor are HTML, JavaScript, and CSS.
- Language Workbenches are really under-represented as a means of implementing a block-based editor. There seems to be an opportunity there.

3.4 RQ3: How are block-based environments developed?

One of our main objectives of this mapping study is to identify how block-based environments are developed in practice. Therefore, we searched the selected papers for the languages and tools used by the authors to develop block-based environments. Based on the data collected (see Table 8) we identified two ways of implementing a block-based editor: either authors rely on existing *libraries and frameworks* or they develop them in a *bespoke* fashion. From the corpus of papers that presented a language, tool, or an extension, 88 of them used libraries for the development of their editors, nine papers developed their bespoke editors entirely from scratch, and 54 papers did not provide a clear insight about how they were implemented, or they did not necessarily introduce a new tool. However, to better understand of how block-based environments are developed, we analyzed the papers to extract the libraries and frameworks used for their development.

Table 9 shows a summary of the resulting list of tools and libraries (for the full list see Appendix G). Similarly, as identified in Section 3.3, most of the papers do not disclose implementation details. However, due to the popularity of

Method	# Languages
Libraries and Frameworks	88
N/A	54
Bespoke	9

Table 8. Method used for developing block-based environments.

Library	# of languages
N/A	62
Blockly	40
Scratch	11
Snap!	7
Scratch 3.0 (Blockly)	3
CT-Blocks	3
App inventor & Blockly	2
Microsoft MakeCode	2
BlocklyDuino	2

Table 9. List of tools used for the development of block-based editors.

some tools for building block-based editors (such as Blockly) in some cases we were able to identify which library was used for their development, even if the authors did not mention them.

As we can observe in Table 26, there are more than 20 libraries or frameworks used by authors. The most popular tool used for developing block-based environments is Blockly. It is one of the few tools specifically designed to support the development of block-based editors, which explains its observed popularity. Moreover, it is interesting to observe that some of the tools used for building the languages are also block-based environments (e.g., Scratch, Snap!), which means developers rely on existing languages and editors for the development of block-based environments. This is interesting and worth studying in the future, perhaps there is a lack of specialized tools for building block-based environments, or simply the Software Language Engineering (SLE) community is not aware of the opportunities offered by block-based environments.

Summary RQ3

- Most of the block-based editors included in this survey were developed using libraries and frameworks; only nine editors were developed in a bespoke fashion.
- More concretely, the most popular libraries used for developing block-based environments are Blockly and Scratch.

3.5 RQ4: What languages offer a block-based editor and what are these languages used for?

As part of this systematic literature review, we sought for the usages of block-based environments. This means, understanding the existing languages that support a block-based editor, and how these languages are being used. While talking to colleagues we noticed that there is a perception that the block-based notation is restricted to computer science education. People also seem to associate block-based environments with children's tools or toys, given their colorful appearance. To check the validity of these perceptions we analyzed the corpus of papers and documented what tools are introduced in each paper and in which fields these tools are used.

The process to extract this data from the papers is described below. First, during the paper review, we collected specific notes in a spreadsheet about each tool. We noted down a possible topic for each tool. Then, with the resulting data, we calculated the number of topics. Initially, we obtained 81 topics, but that classification was not accurate enough to group the papers in a meaningful manner. Thus, to reduce this number and make a more accessible grouping of papers, we defined seven categories: Education, Embedded Computing, Human Computer Interaction, Arts & Creativity, Science, AI, Data Science and Databases, and Software Engineering. This number is significantly lower, and it works appropriately for presenting our findings.

As mentioned previously, we classified the papers into three categories, namely *Research*, *Language*, or *Extension*; and the way we present them in this section differs depending on their type. Research papers are presented with a summary that contains the paper’s topic; and *Languages* and *Extensions* are summarized in a table containing the name of the language/extension, the library used for its development, and its primary usage.

Below we present each category with a brief description and a table with the papers that belong to it. However, to improve the readability of the current manuscript, some categories have more than one table.

Category 1 Education

This category presents the papers that are mostly related to educational purposes. There is a wide range of applications in which block-based environments are used to teach programming or computer science concepts, and other subjects such as chemistry and mathematics. Likewise, this section presents the importance of block-based environments in educational settings and how the modality (blocks or text) affects the learning process.

Programming literacy

In this category, we grouped several topics and points of view regarding using of the block-based modality in programming education. For instance, Weintrop [167] studied the impact of using a block-based environment in education, and Xinogalos et al. [174] investigates students’ perceptions of five popular educational programming environments and the features that introductory programming environments must-have. Similarly, Yoon et al. [175] designed a curriculum that integrates socio-scientific issues in the design and development of mobile apps using App Inventor. Turbak et al. [153] studied the importance of teaching event-based programming in computer science curricula. Dong et al. [42] propose a tinkering environment for students when they struggle in problem-solving activities. Dwyer et al. [43] study the readability of block-based programs by students.

There are different points of view regarding the modality in which programming should be introduced to novice users. Some advocate that visual languages are the best option for introducing novices to programming, while others support text-based languages as the best modality since that is what professional developers use. Thus, researchers have tried to address this topic, and they have work on evaluating the effects that the modality (block-based, text-based, and hybrid) has in the learning process [26, 103, 118, 170, 171]. Franklin et al. [53] study the differences between block-based languages (e.g., Scratch) and text-based languages (e.g., C and Java). Other researchers focus on studying how to ease the transition from a block-based language into a text-based language [81, 172] and the drawbacks users face in this transition [104, 105]. Milne and Ladner [102] study the relevance of accessibility features in block-based environments.

Finally, Table 10 presents the tools aimed at teaching computer science concepts in general and learning environments to support the teaching of computational concepts.

Table 11 shows the languages used to support and transfer computational skills to learners.

Table 12 contains the block-based languages used to teach other subjects such as aerodynamics, Latin language, mathematics, music, and chemistry.

Table 13 presents tools aimed to improve the transition from block-based languages to text-based languages, incorporating block-based notation to existing environments such as spreadsheets, languages to support teachers during grading activities, and, finally, languages to support learners with accessibility issues (e.g., hearing impairments).

⁴This block-based environment is not a complete platform but an extension to an existing system.

Name	Metatool	Topic
MUzECS [14]	Blockly	Explore computer science with a low-cost robot.
RoboScape[91]	NetsBlox	Teach key ideas in computer science using robots.
[164]	MakeCode	Foster computer science education with Lego Mindstorms.
Robot Blockly [169]	Blockly	Programming industrial robot (ABB's Roberta).
HIPE[77]	-	Pedagogy and programming education.
Reduct [8]	-	Gamifying operational semantics.
[134]	Blockly	Introduce young learners to technology with smart homes.
Labenah[3]	-	Learn coding principles via an edutainment application.
Bubbles[121]	Ardublock	Teach programming to children with a robot fish.
Blocks4DS[46]	Blockly	Teach data structures.
Crescendo ⁴ [166]	Snap!	Engage students with programming.
[47-49]	Snap!	Add parallel abstractions to block-based languages.
Pirate Plunder [125]	-	Teach abstractions and reduce code smells with a game.
Resource Rush[95]	Blockly	Teach programming in an open-ended game environment.
Block-C[88]	Openblocks	Learn the C language.
Cake [72]	Blockly	Learn the C language.
Block Pictogramming [68]	Blockly	Learn programming with pictograms.
PRIME [123]	Blockly	Learning environment.
Flip [56]	-	Learn computer science in a bimodal environment.
IntelliBlox [148]	Blockly	Introduce programming in game-based environments.
EduBot [67]	Blockly	Learn programming and STEM modules.
Alg-design ⁴ [159]	CT-Blocks	Teach algorithmic to novices.
Map-Blocks [163]	CT-Blocks	Teach programming with online weather data.
LAPLAYA [63]	Snap!	Block-based environment for middle school students.

Table 10. Languages used to support programming education.

Name	Metatool	Topic
PiBook [28]	Blockly	Transfer computational skills while working on history, biology, and mathematics.
TunePad [58]	Blockly	Introduce computational thinking via sound composition.
C3dio [96]	Blockly	Create 3D environments to enable STEAM education.
Tuk tuk [84]	-	Teach computational thinking concepts using games.
CT-Blocks [160]	-	Teach computational thinking skills.
ChoiCo [60]	Blockly	Teach computational thinking via modifying games.
[93]	-	Teach computational thinking.
[162] ⁴	Scratch	Teach computational thinking using experiments of fractal geometry.

Table 11. Languages used to teach computational thinking skills.

Name	Metatool	Topic
Airblock [25]	Scratch	Teaching programming and aerodynamics.
BlockyTalky [75]	Blockly	Teaching networks.
Ingenium [176]	Blockly	Teaching Latin grammar.
ExManSim [128]	Blockly	Create vignettes for crisis response exercises.
Catrobat [108]	-	Develop mobile applications collaboratively.
MIT App Inventor [114]	Blockly	Develop mobile applications.
EvoBuild ⁴ [165]	Deltatick[173]	Teach and create agent-based models.
Phenomenological gas particle sandbox[10]	NetTango	Teach agent-based computations through phenomenological programming.
M.M.M. [129]	Blockly	Create an agent-based modeling system to learn science.
[13]	NetTango	Use agent-based modeling for other disciplines (e.g., chemistry).
ScratchMaths ⁴ [19]	Scratch	Understand mathematical concepts through programming activities.
[83] ⁴	App inventor	Teach mathematical concepts in primary school.
Tactode[7]	-	Teach math and technology concepts to children.
Sonification Blocks [11]	Blockly	Learn data sonification.

Table 12. Languages used to teach subjects other than programming.

Name	Metatool	Topic
Amphibian [22]	Droplet	Enable switching between blocks and text.
Poliglot [90]	Blockly	Smooth transition from blocks to text in education.
HybridPencilCode [6]	PencilCode and Droplet	Transition from block to text notation.
B@ase [146]	Blockly@arduino	Transition from block to text-based environment.
PyBlockly [142]	Blockly	Add a block-based editor for Python.
Stride [82]	-	Add a frame-based editing (blocks and text) to BlueJ.
XLBlocks [69]	Blockly	Add block-based environment for spreadsheets.
NoBug's SnackBar[156]	-	Measure students' performance in programming tasks.
GradeSnap[100]	Snap!	Assist teachers in grading block-based projects.
StoryBlocks[85]	-	Teach programming to blind users with a tangible game.
Blocks4All [101]	-	Accessibility support for block-based environments.
[111] ⁴	Blocks4All	Accessibility support for block-based environments.
Macblockly ⁴ [29]	Blockly	Block-based support for audiences with disabilities.
[38]	Blockly	Support users with hearing impairments to learn programming.

Table 13. Block-based languages applications.

Category 2 Embedded computing

This category contains all the papers that were associated with some form of embedded computing. This includes languages for programming and manipulation of robots, microcontrollers, and other embedded systems.

Following the idea of embedded computing with a block-based environment, [37] present the benefits of using a block-based language for manipulating and teaching physical components.

Table 14 presents all the languages we classified as being part of the embedded computing category. This includes programming robots, embedded systems, Internet of Things (IoT) devices, and controllers.

Name	Metatool	Topic
MakeCode [15]	Blockly	Programming environment for microcontrollers.
NaoBlocks [143]	Blockly	Manipulate Nao robots.
Coblox [136]	Blockly	Programming ABB's industrial robots.
ROS educational ⁴ [147]	Snap!	Manipulate ROS-enabled platforms.
Robobo [16, 17]	Scratch	Manipulate advanced sensors.
EUD-MARS [2]	Blockly	Use model-driven approach to program robots.
CoBlox [168]	Blockly	Interface for Roberta a single-armed industrial robot.
MakerArcade [135]	MakeCode	Create gaming experiences through physical computing.
UNC++Duino [18]	BlocklyDuino	Program robots to teach CS concepts.
The Coffee Platform [131]	Blockly	Support computational thinking skills through robotics.
LearnBlock [12]	-	Robot-agnostic educational tool.
RP [31]	Blockly	Affordable robot (software and hardware) for education.
mBlock [92]	-	Teach CS and electronics with affordable robots.
CAPIRCI [20]	-	Support collaborative robot programming.
CODAL [40]	Blockly and MakeCode	Create effective and efficient code for embedded systems.
OPEL TDO [80]	Blockly	Test programmable logic controllers by end-users.
Block-based data fusion [23]	-	Define complex event processing pipelines for smart cities.

Table 14. Block-based languages in embedded computing.

Category 3 Human Computer Interaction (HCI)

This category contains papers that focus on a wide variety of aspects of Human-Computer Interaction. We identified aspects such as the usability of block-based environments and their limitations, comparison between different user interfaces (e.g., TUIs, GUIs, and brain-computer interfaces), adding code hints to block-based environment, and supporting end-user development (EUD) through block-based languages.

Most of the papers that fall in this category present a language as summarized in Table 15. However, three papers present a more theoretical view. For instance, Holwerda and Hermans [64] present an evaluation to measure the usability of Ardublockly [116], a block-based environment for programming Arduino boards. This evaluation was done using the cognitive dimensions of notations framework [21]. Likewise, Rough and Quigley [126] present the challenges of traditional usability evaluations. Almjally et al. [4] present an empirical study that compares the usage of a block-based language using Tangible User Interfaces (TUIs) and Graphical User Interfaces (GUIs).

Name	Metatool	Topic
Shelves ⁴ [65]	Blockly	Usability of block-based environment.
[97] ⁴	iSnap! ⁴ [119]	Improve code hints in block-based environment.
iSnap ⁴ [120]	Snap!	Add intelligent tutoring system features to Snap!.
[5]	-	Add custom keyboard to block-based languages.
Enrect [144]	-	Introduce noted-link interfaces to represent variables.
Multi-device Grace [133]	Tiled Grace	Support for multi-device environments.
ARcadia [76]	MakeCode	Prototype tangible user interfaces.
VEDILS [106, 107]	App inventor and Blockly	Support end-users to create mobile learning applications with augmented reality.
Jeeves [127]	-	Support end-users to develop applications.
TAPAS [155]	-	Create workflow applications (e.g., IFTTT [66]).
TAPASPlay ⁴ [154]	TAPAS	Support EUD via collaborative game-based learning.
StoryMakAR [54]	BlocklyDuino	Support storytelling with augmented reality and IoT.
Aesop [130]	-	Create digital storytelling experiences.
Neuroblock[35, 36]	Scratch	Build applications driven by neurophysiological data.
NeuroSquare [99]	Blockly	Support brain-computer interfaces using blocks and flow charts.
Neuroflow [62]	Blockly	Block-flow environment for brain-computer interfaces.
Touchstone2 [44]	-	Tool to design HCI experiments.

Table 15. Block-based languages in human-computer interaction.

Category 4 Arts & Creativity

This category contains languages used for exploring creativity or as a medium for creating art through block-based constructs or by analyzing users' patterns as a result of their programming activities. Languages that fall in this category are presented in Table 16.

Name	Metatool	Topic
Quando [141]	Blockly	Create interactive digital exhibits for gallery visitors.
BlockArt ⁴ [41]	Scratch	Visualize programming patterns in Scratch.

Table 16. Block-based languages in creativity.

Category 5 Science

In this category, we found a single language using the block metaphor for conducting experiments in biology, see Table 17.

Name	Metatool	Topic
OpenLH [55]	Blockly	Liquid handling system to conduct live biology experiments.

Table 17. Block-based languages in Science.

Category 6 Artificial intelligence, data science, and databases

This section contains block-based languages applied to the domain of artificial intelligence and data science. This includes topics such as machine learning, chatbots, data science topics in general, and databases, as shown in Table 18.

Name	Metatool	Topic
ScratchThAI ⁴ [74]	Scratch	Support computational thinking with a chatbot.
SnAIp ⁴ [70]	Snap!	Enable machine learning within Snap!.
AlpacaML ⁴ [177]	Scratch 3.0	Test, evaluate, and refine ML models.
BlockPy [34]	Blockly	Introductory programming environment for data science.
Scratch Community Blocks ⁴ [39]	Scratch	Analysis and visualization of data coming from Scratch.
BlockArt ⁴ [41]	Scratch	Visualization tool of programming in Scratch.
[50] ⁴	Scratch 3.0	Engage learners in exploring and making sense of data.
Snap!DSS ⁴ [59]	Snap!	Allow data stream analyses and visualization.
DBSnap++ [138]	Snap!	Enable specification of dynamic data-driven programs.
DBSnap [137]	-	Build database queries.
BlocklySQL [117]	Blockly	Block-based editor for SQL.
DB-Learn [161]	CT-Blocks	Teach relational algebra concepts.

Table 18. Block-based languages in artificial intelligence and data science.

Category 7 Software engineering

This category contains different papers that present languages and proceedings that study block-based environments usage in software engineering. Therefore, the reader will find various topics such as code smells in block-based programs, security, testing, refactoring, debugging facilities, and specialized tools for developing block-based languages.

In this category, we have grouped some papers that present a more theoretical view of the application of block-based languages. Hermans and Aivaloglou [61] study code smells in the context of a block-based environment, particularly in Scratch programs, and Techapalokul and Tilevich [149] study code quality in block-based programs using a methodology for code smells. Swidan et al. [145] study naming patterns of Scratch programs' variables and procedures following this direction. In contrast, Robles et al. [122] identify software clones in Scratch projects. The usage of static analysis techniques in block-based programs is beneficial, as shown by Jatzlau et al. [71]. They use static analysis techniques of Snap! programs to learn from programmers' behaviors. Likewise, Aivaloglou and Hermans [1] use static analysis techniques to explore Scratch programs' characteristics in software repositories. Finally, Tenorio et al. [152] study different debugging strategies in block-based programs.

Name	Metatool	Topic
ViSPE [110]	Scratch	Policy editor for XACML.
XACML policy editor [109]	Scratch	XACML policy editor.

Table 19. Block-based Languages in security.

Name	Metatool	Topic
Extension Whisker [140]	-	Testing framework for Scratch
Extension [132]	Blockly	Add block-level debugging features to block-based environment.
Extension [86]	Blockly	Stepwise support for block-based environments.
Processing BBE [87]	-	Create visual block-based domain-specific languages.
Polymorphic Blocks [94]	-	Represent complex structures and visual type information with block-based UI.
LitterBox [52]	Scratch	Detecting bugs in Scratch programs.
QIS [151]	Scratch	Refactoring infrastructure for Scratch.
[150] ⁴	Scratch 3.0	Automated refactoring tool for Scratch.
Behavioral Blockly [9]	Blockly	Support behavioral programming.

Table 20. Block-based Languages in software engineering.

Table 19 shows two languages that we identified are used in topics related to security to define access control policies. Table 20 shows the list of languages used in different topics of software engineering. Based on these tools, we highlight the appearance of one tool, *Processing BBE*, designed specifically for creating block-based environments.

3.6 Block-based editors popularity

So far, we have presented all the block-based languages that we identified in the papers included in this study. As we have seen so far, most of the studies refer to Scratch as the most popular block-based environment. To verify this, we manually kept track of the occurrences of each tool in each paper. We started with an initial set of block-based languages that we obtained manually from searching at the most popular tools (see Section 4). When we had the initial set of languages, we proceeded to read the papers, and in a spreadsheet, we marked when a tool was mentioned and in which paper. As we were reading papers, we added new languages that appeared to the set of block-based languages. It is important to remark that in some cases, papers not only introduced a tool, but they also mention related tools that we also include in the list of tools. This process has an explicit limitation since the discovery of languages is incremental as we read the papers. Therefore, we made a sanity check using the same tool we developed and presented in Section 3.3 to mine the corpus of PDF files and collect the occurrences of each tool.

Figure 6 shows a summary of the 11 most popular tools (see Appendix E for the full list). Since we used a program to mine the PDFs to double-check our manual results, the tool is not 100% accurate. In Section 5, we present some of the limitations of the tool.

As speculated at the beginning, our results show that Scratch is indeed the language most mentioned in all the papers; it was mentioned in more than 80 of the papers of this study. Similarly, Blockly is the second most mentioned language, even though it is not a language but a library for defining block-based languages. The complete list of tools identified in this study and the number of papers in which they appear are shown in Appendix E.

4 NON-SYSTEMATIC REVIEW OF BLOCK-BASED ENVIRONMENTS

As introduced before, we also conducted a less-systematic exploration using standard Google search to find information about block-based environments that were not necessarily published academically. Table 21 presents a summary of our

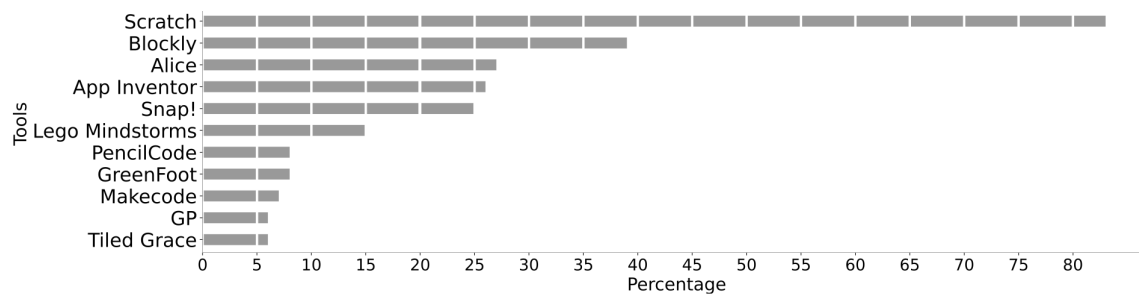


Fig. 6. Popularity of block-based environments across publications.

findings after analyzing and trying out each of the tools resulting from the search process. Likewise, it also contains a set of features empirically collected by the first author after testing each language or tool. The process to collect these features was by trying each tool and collecting its features in a spreadsheet. Since all block-based environments do not offer the same features, a few tools had to be tested more than once because some features were included in the spreadsheet after testing the tool. The table is divided into seven columns, and all columns except the first one are subdivided into other columns.

(i) *Name* represents the name of the tool or the language, (ii) *Editor* represents the different components present in a code editor (e.g., mode, error marking, and stage), (iii) *Focus* represents whether the tool is an application, a language that supports the developing block-based environments, or both, (iv) *Deployment* shows the different models in which the tools are being offered, namely as standalone, mobile, or as Software as a Service (SaaS), (v) *Domain* represents the application domain where the tool is used, (vi) *Execution* is how the tool executes an application. We identified mainly two modes: live and pressing an execution button (manual), and (vii) *Licensing* shows the three main types in which the tools are offered.

As the reader might have noticed, these features were used as a basis for the definition of the feature diagram of block-based environments in Section 3.2. Using this manual exploration of all available tools we discovered most of the features of block-based environments. The other features were discovered after the systematic literature review process described earlier. As described in the methodology, all tools listed in the table were tested by the first author. Likewise, thanks to the mixed methodology, we were capable of identifying tools that we could not have discovered by relying solely on a systematic approach. Therefore, the less-systematic exploration allowed us to discover 49 tools; from this number, only three tools (*BlockPy*, *CoBlox*, and *Tuk tuk*) appeared in both the systematic and the less-systematic approach. Some interesting facts of using this mixed methodology are discussed in Section 6.

5 THREATS TO VALIDITY

A systematic literature review (SLR) is a research methodology used to obtain a complete overview of a particular topic or domain. Based on that, we followed the Kitchenham et al. [78] guidelines, and we defined our protocol for conducting this study. We identified some threats to validity that we discuss in more detail in this section.

5.1 External validity

SLRs are conducted to present a summary of a particular topic or domain. Although authors try to reduce their bias as much as possible, it is almost impossible to eradicate it. Thus, this is one of the main threats to validity and a critical

Name	Editor							Focus	Deployment			Domain							Execution		Licensing				
	Stage								Language	Standalone	Mobile	SaaS	Gaming	Animation	Programming Hardware	Programming	SE tools	Education	Multi-agent modeling	Live	Manual	Academic	Commercial	Open-source	
	Single mode	Dual mode	Textual	Visual	Hardware	Feedback	Error marking																		Application
Pencil code																									
Scratch																									
Alice																									
Blockly																									
Mindstorms																									
App inventor																									
Pocket Code																									
Deltatick																									
Frog pond																									
StarLogo TNG																									
Turtle art																									
PicoBlocks																									
Robobuilder																									
OpenBlocks																									
miniBloq																									
GP																									
Snap!																									
Microblocks																									
Makecode																									
Waterbear																									
Looking Glass																									
Greenfoot																									
Applab																									
StarLogo Nova																									
Tynker																									
Hopscotch																									
AutoBlocks																									
BlockPy																									
Kodika																									
Sphero Sprk																									
Stencyl																									
Tynker																									

Table 21. Tools identified using the non systematic approach via standard Google search.

aspect of these studies. In the design of our protocol, we tried to minimize as much as possible our bias by defining three filters for including the final set of papers. Moreover, two authors discussed the inclusion and exclusion criteria for a sample of ten papers. Nonetheless, it is essential to mention that since we were looking at specific research questions, this study can never be entirely unbiased, and it is focused on addressing these questions. The queries and the sources of information used in this study prevent us from being fully unbiased. Nonetheless, we tried to keep the current study as broad as possible; in the paper selection, a wide variety of papers came from different communities, venues, and areas of expertise. Moreover, in general, the notion of block-based environments is ambiguous; this term is used to refer to two different topics. On the one hand, visual programming environments that adopt the jigsaw metaphor for creating programs (discussed in this paper), and on the other hand, the notion of blocks in a block diagram (e.g., Simulink), which is often used in simulation applications and model-based design.

5.2 Internal validity

Since the data collection was a manual task, we consider it essential to conduct a sanity check using automated tools. For this purpose, we developed a tool for scanning and mining PDF files and checks whether a given list of words appears in the file's content. There are some known caveats which concern the accuracy and correctness of the tool. First, reading and mining PDF files is not an easy task, mainly because PDF files do not share a standard structure.

Thus, some files cannot be opened, or all the text is not parseable. Second, the list of words was manually defined. In the case of programming languages popularity, it was obtained from the TIOBE index [27], which made it more accessible. However, to double-check the languages' popularity, this list was a manual process, which started from a list of languages obtained via a non-systematic method. This list of languages was improved by taking manual notes of new tools presented in papers and their related work. Therefore, it could be the case that the last paper read by the authors introduced a new tool, which of course, was not marked in the previous papers since it was not found yet. However, thanks to the automated tool, we can detect across all the papers if the tool is mentioned or not. In this direction, the tool results are not 100 % accurate due to different factors. (i) *Ambiguous words*. Words in the input list are valid words in English. For instance, *Scratch* or *Go*. Thus, the tool does not differentiate whether it is an English word or refers to a block-based editor or a programming language. (ii) *Punctuation marks*. The tool compares word by word each of the words in the input list against the text. This means that if a word in the input text appears in the text next to a punctuation mark (e.g., colon or comma), the tool produces a false negative result. The tool says that the word is not present, even though it is present, but it does not capture it since it is next to a punctuation mark (without a blank space in the middle). To measure possible errors in the tool, we sampled ten papers and five programming languages to check how accurate the tool's results are. We calculated type I and type II errors based on the sample to identify the numbers of false positives and false negatives, respectively. The results obtained show that the sensitivity of the tool is 75%. This means that there is a rate of false negatives of 25%. In other words, in 25% of the cases, the tool says that the word is not present in the document, but it is. Similarly, the tool's specificity is about 82,6%, which means that the false-positive rate is 17,4%. In 17% of the cases, the tool said a word was present in the document, even though the word was not present.

In both cases, the tool can be fine-tuned so that both the sensitivity and specificity improve by considering the corner cases previously mentioned. However, that is not the main focus of the current paper. We developed this tool as a sanity check to refine the results obtained during the manual inspection.

In Section 3.3, where we present the programming languages used, some papers do not mention how they were implemented. For instance, we could have assumed that when they use Blockly, the editor was implemented using JavaScript, which is the most popular language used for using Blockly. Nevertheless, this is not true for all the cases, because it is also available in other programming languages. Therefore, we decided not to make assumptions about this.

As presented in the protocol, we only considered four academic databases to obtain the academic papers, and the non-systematic search gave us practical languages that do not necessarily have an academic publication. However, the latter means that this part is not easily reproducible.

6 DISCUSSION

We identified three main ways that developers follow to create block-based environments. The first approach is by extending an existing language. Twenty-seven of the languages included in this study were developed using this approach. The second one is by using a library that supports the development of such languages. As expected, this is the most popular solution we found in the tools we discovered. Sixty-one languages were developed using other libraries since this reduces the development effort. Finally, the third option is a bespoke implementation. Based on our corpus, only nine languages used this approach. It is important to remark that the previous methods for implementing block-based environments are defined based only on our observations. This might not be true for all cases, given that many authors did not mention any implementation details.

It is interesting to see in the data that there are not many tools that support the whole development cycle of block-based environments. There are specialized libraries for creating concrete pieces of them, but most of these environments

rely on code generators. For instance, Blockly is used for describing the UI of the language, and then programs must be compiled to a target language (e.g., Python). We found two tools ([87, 158]) to develop software languages with a built-in block-based editor. However, these two tools are relatively new or not widely adopted; none of the languages presented in this paper was implemented using them. Likewise, it is relevant to mention that the approach proposed by [87] relies on code generators. Instead, [158] relies on language workbench technology for defining both the syntax and the semantics of languages, which makes such languages also usable outside a block-based editor in a traditional IDE.

Based on the collected data, it is evident that the most popular programming language for implementing block-based environments is JavaScript (Table 9). This seems an interesting outlier, but it should not be seen independently from the following observation. Most block-based environments were implemented using Blockly, which is a library implemented in JavaScript. Even though, Blockly offers implementations in other programming languages (e.g., Swift), these have been deprecated and are no longer maintained by the Blockly Team. Moreover, several block-based languages are implemented as web applications, which also explains the vast popularity of using JavaScript for creating block-based languages.

As shown in Section 3.4, there is a limited number of libraries for developing block-based environments. Therefore, we see that many authors rely on existing block-based environments to build their own. Surprisingly, specialized language engineering tools (e.g., LWBs) are not used in this domain. JastAdd [112] and ANTLR [113] were used for developing two environments, each one. Our research resulted in *Kogi* [158], that uses the Rascal LWB [115] to create block-based editors for new and existing languages. This to make block-based editors part of the generic services offered by LWBs. However, this tool was not considered in this survey because it was published afterwards.

Another interesting observation that resulted from this study is using mixed methods (systematic and non-systematic searches). As presented in this survey, we see differences between the results obtained from the systematic literature review and the non-systematic tool review. We identified some hypotheses behind these differences. First, some tools are developed to address a specific problem, which is not always followed by a scientific publication. Moreover, there are also industrial applications. Their primary focus is not necessarily the development of scientific publications and following existing literature but to address business requirements and make things work. Another critical aspect of industrial applications is their visibility; sometimes, they are not disclosed due to intellectual property rights. As we underlined in our data, the difference is remarkable. From the 35 languages and tools that we identified in the non-systematic approach, only 3 had a research paper included in this review. This means that more than 91% of the tools would not have been included if we did not conduct a search of non-academic literature and tools.

7 RELATED WORK

Coronado et al. [33] present a literature review about 16 visual programming environments to foster end-user development (EUD) of applications that involve robots with social capabilities. This survey focuses on visual programming environments for non-professional programmers, and they highlight mainly two goals. The first one is to present a list of the tools with their technical features, and the second, to present the open challenges in the development of visual programming environments for end-users. McGill and Decker [98] conducted a systematic literature review and propose a taxonomy for tools, languages, and environments (TLEs) used in computer education. Their main focus is on studying TLEs used in primary, secondary, and post-secondary education. Based on their study, they propose a TLEs taxonomy. Solomon et al. [139] present the history of Logo, a programming environment designed for children

to explore mathematical concepts. This is the main predecessor of current notions of block-based environments for end-users.

Rough and Quigley [127] present a perspective of end-user development (EUD) for creating and customizing software by end-users, as end-users outnumbered professional programmers. As a result of their work, they propose some design recommendations to support EUD activities, particularly the creation of software that allows novice users to create apps that collect data (e.g., experience sampling). This paper follows a similar methodology. They queried computer science databases and a non-systematic approach through Google search to get non-academic tools.

8 CONCLUSIONS AND FUTURE WORK

This paper presents an overview of block-based environments and their features. Also, it presents a detailed view of how these programming environments are developed and the technologies involved in this process. We listed and summarized more than one hundred languages and extensions, which were grouped into seven categories. These categories highlight the fact that block-based environments have a broader scope than computer science education. The results show that authors do not mention implementation details or possible troubles that the development of a block-based editor has. Moreover, there is a vast diversity of applications in which the block-based metaphor is adopted (e.g., arts, education, science, robotics). Yet, there is a lack of tool support for developing a whole language that supports a block-based editor. Existing tools do not support the whole development cycle of a language. In most cases, designers of block-based environments rely on code generators for defining the semantics of the languages. We believe that the usage of meta-programming technologies, such as found in Language Workbenches, would enable engineers to fully develop a language and obtain a block-based editor almost “for free”, as is the case already for textual editors. Likewise, we confirmed that Scratch has had a significant impact on the development of most of current block-based environments, both conceptually and technically.

Another interesting conclusion of the current survey is that using different methods and sources (systematic and less-systematic, academic and non-academic) allowed us to synthesize a more complete overview of this particular topic than would otherwise be possible. In particular, the less-systematic approach to collect information from non-academic sources presented findings complementary to the systematic literature study, which were also fundamental to the interpretation of the data from the systematic literature study.

We also provided an overview of academic research on usability and learnability of block-based editors (as compared to text editors) and other studies of large collections of block-based programs.

As future work, we foresee different directions: (i) Study what are the best practices for using and implementing block-based editors. The current paper presents an overview of the features we identified across languages. However, it is interesting to explore the particularities of block-based interfaces to improve the users’ programming experience; and how this can be used to implement better block-based editors. (ii) Explore the integration of block-based editors as part of the default set of services offered by specialized tooling for language development (e.g., language workbenches). (iii) Study the lack of tools that support the creation and generation of block-based editors. (iv) Support dynamic aspects of languages in block-based environments (e.g., debugging and live programming). (v) Investigate hybrid environments in which parts of blocks are text-based, depending on the language construct’s nature. This to improve the usability and efficiency between drag and drop and writing textual code.

REFERENCES

- [1] Efthimia Aivaloglou and Felienne Hermans. 2016. How Kids Code and How We Know: An Exploratory Study on the Scratch Repository. In *Proceedings of the 2016 ACM Conference on International Computing Education Research* (Melbourne, VIC, Australia) (ICER '16). ACM, New York, NY, USA, 53–61. <https://doi.org/10.1145/2960310.2960325>
- [2] P. A. Akiki, P. A. Akiki, A. K. Bandara, and Y. Yu. 2020. EUD-MARS: End-user development of model-driven adaptive robotics software systems. *Science of Computer Programming* 200 (2020). <https://doi.org/10.1016/j.scico.2020.102534>
- [3] B. Alkadhi, S. Alsaif, A. Alangri, F. Alkallas, H. Aljadou, and N. Altamimi. 2019. Labenah: An Arabic Block-Based Interactive Programming Environment for Children. The Journey of Learning and Playing. In *HCI International 2019 - Posters*. Springer, Cham, 179–187.
- [4] A. Almjally, K. Howland, and J. Good. 2020. Comparing TUIs and GUIs for Primary School Programming. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (Portland, OR, USA) (SIGCSE '20). ACM, New York, NY, USA, 521–527. <https://doi.org/10.1145/3328778.3366851>
- [5] I. Almusaly, R. Metoyer, and C. Jensen. 2018. Evaluation of A Visual Programming Keyboard on Touchscreen Devices. In *2018 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 57–64. <https://doi.org/10.1109/VLHCC.2018.8506557>
- [6] Hussein Alrubaye, Stephanie Ludi, and Mohamed Wiem Mkaouer. 2019. Comparison of Block-Based and Hybrid-Based Environments in Transferring Programming Skills to Text-Based Environments. In *Proceedings of the 29th Annual International Conference on Computer Science and Software Engineering* (Toronto, Ontario, Canada) (CASCON '19). IBM Corp., USA, 100–109.
- [7] Márcia Alves, Armando Sousa, and Ângela Cardoso. 2020. Web Based Robotic Simulator for Tactode Tangible Block Programming System. In *Robot 2019: Fourth Iberian Robotics Conference*, Manuel F. Silva, José Luís Lima, Luís Paulo Reis, Alberto Sanfeliu, and Danilo Tardioli (Eds.). Springer International Publishing, Cham, 490–501.
- [8] Ian Arawjo, Cheng-Yao Wang, Andrew C. Myers, Erik Andersen, and François Guimbretière. 2017. Teaching Programming with Gamified Semantics. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) (CHI '17). ACM, New York, NY, USA, 4911–4923. <https://doi.org/10.1145/3025453.3025711>
- [9] Adiel Ashrov, Assaf Marron, Gera Weiss, and Guy Wiener. 2015. A use-case for behavioral programming: An architecture in JavaScript and Blockly for interactive applications with cross-cutting scenarios. *Science of Computer Programming* 98 (2015), 268–292. <https://doi.org/10.1016/j.scico.2014.01.017>
- [10] Umit Aslan, Nicholas LaGrassa, Michael Horn, and Uri Wilensky. 2020. Phenomenological Programming: A Novel Approach to Designing Domain Specific Programming Environments for Science Learning. In *Proceedings of the Interaction Design and Children Conference* (London, United Kingdom) (IDC '20). ACM, New York, NY, USA, 299–310. <https://doi.org/10.1145/3392063.3394428>
- [11] Jack Atherton and Paulo Blikstein. 2017. Sonification Blocks: A Block-Based Programming Environment For Embodied Data Sonification. In *Proceedings of the 2017 Conference on Interaction Design and Children* (Stanford, California, USA) (IDC '17). ACM, New York, NY, USA, 733–736. <https://doi.org/10.1145/3078072.3091992>
- [12] P. Bachiller-Burgos, I. Barbecho, L. V. Calderita, P. Bustos, and L. J. Manso. 2020. LearnBlock: A Robot-Agnostic Educational Programming Tool. *IEEE Access* 8 (2020), 30012–30026. <https://doi.org/10.1109/ACCESS.2020.2972410>
- [13] C. Bain, G. Anton, M. Horn, and U. Wilensky. 2019. Position: Building Blocks for Agent-based Modeling Can Scaffold Computational Thinking Engagement in STEM Classrooms. In *IEEE Blocks and Beyond Workshop*. 1–4. <https://doi.org/10.1109/BB48857.2019.8941204>
- [14] M. Bajzek, H. Bort, O. Hunpatin, L. Mivshek, T. Much, C. O'Hare, and D. Brylow. 2015. MUzECS: Embedded blocks for exploring computer science. In *2015 IEEE Blocks and Beyond Workshop (Blocks and Beyond)*. 127–132. <https://doi.org/10.1109/BLOCKS.2015.7369021>
- [15] Thomas Ball, Abhijith Chatra, Peli de Halleux, Steve Hodges, Michał Moskal, and Jacqueline Russell. 2019. Microsoft MakeCode: Embedded Programming for Education, in Blocks and TypeScript. In *Proceedings of the 2019 ACM SIGPLAN Symposium on SPLASH-E* (Athens, Greece). ACM, 7–12. <https://doi.org/10.1145/3358711.3361630>
- [16] Francisco Bellas, Alma Mallo, Martin Naya, Daniel Souto, Alvaro Deibe, Abraham Prieto, and Richard J. Duro. 2020. STEAM Approach to Autonomous Robotics Curriculum for High School Using the Robobo Robot. In *Robotics in Education*. Springer International Publishing, Cham, 77–89.
- [17] F. Bellas, M. Naya, G. Varela, L. Llamas, A. Prieto, J. C. Becerra, M. Bautista, A. Faiña, and R. Duro. 2018. The Robobo Project: Bringing Educational Robotics Closer to Real-World Applications. In *Robotics in Education*. Springer, Cham.
- [18] Luciana Benotti, Marcos J. Gómez, and Cecilia Martínez. 2017. UNC++Duino: A Kit for Learning to Program Robots in Python and C++ Starting from Blocks. In *Robotics in Education*, Munir Merdan, Wilfried Lepuschitz, Gottfried Koppensteiner, and Richard Balogh (Eds.). Springer International Publishing, Cham, 181–192.
- [19] Laura Benton, Piers Saunders, Ivan Kalas, Celia Hoyles, and Richard Noss. 2018. Designing for learning mathematics through programming: A case study of pupils engaging with place value. *International Journal of Child-Computer Interaction* 16 (2018), 68–76. <https://doi.org/10.1016/j.ijcci.2017.12.004>
- [20] Sara Beschi, Daniela Fogli, and Fabio Tampalini. 2019. CAPIRCI: A Multi-modal System for Collaborative Robot Programming. In *End-User Development*. Springer International Publishing, Cham, 51–66.
- [21] A. F. Blackwell, C. Britton, A. Cox, T. R. G. Green, C. Gurr, G. Kadoda, M. S. Kutar, M. Loomes, C. L. Nehaniv, M. Petre, C. Roast, C. Roe, A. Wong, and R. M. Young. 2001. Cognitive Dimensions of Notations: Design Tools for Cognitive Technology. In *Cognitive Technology: Instruments of Mind*.

Springer Berlin Heidelberg, Berlin, Heidelberg, 325–341.

- [22] J. Blanchard, C. Gardner-McCune, and L. Anthony. 2019. Amphibian: Dual-Modality Representation in Integrated Development Environments. In *IEEE Blocks and Beyond Workshop*. <https://doi.org/10.1109/BB48857.2019.8941213>
- [23] D. Bonino, F. Rizzo, C. Pastrone, J. A. C. Soto, M. Ahlsen, and M. Axling. 2016. Block-based realtime big-data processing for smart cities. In *2016 IEEE International Smart Cities Conference*. 1–6. <https://doi.org/10.1109/ISC2.2016.7580768>
- [24] M. Bravenboer, K. Kalleberg, R. Vermaas, and E. Visser. 2008. Stratego/XT 0.17. A language and toolset for program transformation. *Science of Computer Programming* 72, 1-2 (2008), 52–70. <https://doi.org/10.1016/j.scico.2007.11.003>
- [25] Benedikt Breuch and Martin Fislake. 2020. First Steps in Teaching Robotics with Drones. In *Robotics in Education*. Springer International Publishing, Cham, 138–144.
- [26] Neil C.C. Brown, Jens Mönig, Anthony Bau, and David Weintrop. 2016. Panel: Future Directions of Block-based Programming. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education (Memphis, Tennessee, USA) (SIGCSE '16)*. ACM, New York, NY, USA, 315–316. <https://doi.org/10.1145/2839509.2844661>
- [27] TIOBE Software BV. 2021. *TIOBE Index for January 2021*. <https://www.tiobe.com/tiobe-index/>
- [28] André Campos, Mário Rodrigues, Alberto Signoretti, and Marlene Amorim. 2018. piBook: Introducing Computational Thinking to Diversified Audiences. In *Computers Supported Education*. Springer, Cham, 179–195.
- [29] Logan B. Caraco, Sebastian Deibel, Yufan Ma, and Lauren R. Milne. 2019. Making the Blockly Library Accessible via Touchscreen. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility (Pittsburgh, PA, USA)*. ACM, New York, NY, USA, 648–650. <https://doi.org/10.1145/3308561.3354589>
- [30] P. Charles, R. M. Fuhrer, and S. M. Sutton. 2007. IMP: A Meta-Tooling Platform for Creating Language-Specific Ides in Eclipse. In *Proceedings of the 22th IEEE/ACM International Conference on Automated Software Engineering (Atlanta, Georgia, USA) (ASE '07)*. ACM, New York, NY, USA, 485–488. <https://doi.org/10.1145/1321631.1321715>
- [31] Avraam Chatzopoulos, Michail Papoutsidakis, Michail Kalogiannakis, and Sarantos Psycharis. 2020. Innovative Robot for Educational Robotics and STEM. In *Intelligent Tutoring Systems*. Springer International Publishing, Cham, 95–104.
- [32] Jacob Cohen. 1960. A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement* 20, 1 (1960), 37–46. <https://doi.org/10.1177/001316446002000104>
- [33] Enrique Coronado, Fulvio Mastrogiovanni, Bipin Indurkha, and Gentiane Venture. 2020. Visual Programming Environments for End-User Development of intelligent and social robots, a systematic review. *Journal of Computer Languages* 58 (2020), 100970. <https://doi.org/10.1016/j.cola.2020.100970>
- [34] A. Cory Bart, J. Tibau, D. Kafura, C. A. Shaffer, and E. Tilevich. 2017. Design and Evaluation of a Block-based Environment with a Data Science Context. *IEEE Transactions on Emerging Topics in Computing* (2017), 1–1. <https://doi.org/10.1109/TETC.2017.2729585>
- [35] Chris S. Crawford, Christina Gardner-McCune, and Juan E. Gilbert. 2018. Brain-Computer Interface for Novice Programmers. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education (Baltimore, Maryland, USA) (SIGCSE '18)*. ACM, New York, NY, USA, 32–37. <https://doi.org/10.1145/3159450.3159603>
- [36] Chris S. Crawford and Juan E. Gilbert. 2019. Brains and Blocks: Introducing Novice Programmers to Brain-Computer Interface Application Development. *ACM Trans. Comput. Educ.* 19, 4 (July 2019), 27. <https://doi.org/10.1145/3335815>
- [37] M. Cápay and N. Klimová. 2019. Engage Your Students via Physical Computing!. In *2019 IEEE Global Engineering Education Conference (EDUCON)*. 1216–1223. <https://doi.org/10.1109/EDUCON.2019.8725101>
- [38] M. Das, D. Marghitu, F. Jamshidi, M. Mandala, and A. Howard. 2020. Accessible Computer Science for K-12 Students with Hearing Impairments. In *Universal Access in Human-Computer Interaction. Applications and Practice*. Springer, Cham, 173–183.
- [39] Sayamindu Dasgupta and Benjamin Mako Hill. 2017. Scratch Community Blocks: Supporting Children As Data Scientists. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (Denver, Colorado, USA) (CHI '17)*. ACM, New York, NY, USA, 3620–3631. <https://doi.org/10.1145/3025453.3025847>
- [40] James Devine, Joe Finney, Peli de Halleux, Michał Moskal, Thomas Ball, and Steve Hodges. 2019. MakeCode and CODAL: Intuitive and efficient embedded systems programming for education. *Journal of Systems Architecture* 98 (2019), 468–483. <https://doi.org/10.1016/j.sysarc.2019.05.005>
- [41] S. Dhariwal. 2019. BlockArt: Visualizing the 'Hundred Languages' of Code in Children's Creations. In *Proceedings of the 2019 on Creativity and Cognition (San Diego, CA, USA)*. ACM, USA, 633–639. <https://doi.org/10.1145/3325480.3326585>
- [42] Y. Dong, S. Marwan, V. Catete, T. Price, and T. Barnes. 2019. Defining Tinkering Behavior in Open-ended Block-based Programming Assignments. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education (Minneapolis, MN, USA) (SIGCSE '19)*. ACM, New York, NY, USA, 1204–1210. <https://doi.org/10.1145/3287324.3287437>
- [43] H. Dwyer, C. Hill, A. Hansen, A. Iveland, D. Franklin, and D. Harlow. 2015. Fourth Grade Students Reading Block-Based Programs: Predictions, Visual Cues, and Affordances. In *Proceedings of the Eleventh Annual International Conference on International Computing Education Research*. ACM, USA, 111–119. <https://doi.org/10.1145/2787622.2787729>
- [44] Alexander Eiselmayer. 2020. Supporting the Design and Analysis of HCI Experiments. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (Honolulu, HI, USA) (CHI EA '20)*. ACM, New York, NY, USA, 1–8. <https://doi.org/10.1145/3334480.3375038>
- [45] Sarah Esper, Stephen R. Foster, and William G. Griswold. 2013. On the Nature of Fires and How to Spark Them When You're Not There. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education (Denver, Colorado, USA) (SIGCSE '13)*. ACM, New York, NY, USA,

Manuscript submitted to ACM

- 305–310. <https://doi.org/10.1145/2445196.2445290>
- [46] P. G. Feijó-García, S. Wang, J. Cai, N. Polavarapu, C. Gardner-McCune, and E. D. Ragan. 2019. Design and evaluation of a scaffolded block-based learning environment for hierarchical data structures. In *2019 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 145–149. <https://doi.org/10.1109/VLHCC.2019.8818759>
 - [47] A. Feng and W. Feng. 2016. Parallel Programming with Pictures in a Snap!. In *2016 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW)*. 950–957. <https://doi.org/10.1109/IPDPSW.2016.194>
 - [48] Annette Feng, Mark Gardner, and Wu chun Feng. 2017. Parallel programming with pictures is a Snap! *J. Parallel and Distrib. Comput.* 105 (2017), 150–162. <https://doi.org/10.1016/j.jpdc.2017.01.018> Keeping up with Technology: Teaching Parallel, Distributed and High-Performance Computing.
 - [49] A. Feng, E. Tilevich, and W. Feng. 2015. Block-based programming abstractions for explicit parallel computing. In *2015 IEEE Blocks and Beyond Workshop (Blocks and Beyond)*. 71–75. <https://doi.org/10.1109/BLOCKS.2015.7369006>
 - [50] Cassia Fernandez. 2020. Combining Computational and Science Practices in K-12 Education. In *Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts (London, United Kingdom) (IDC '20)*. ACM, New York, NY, USA, 25–29. <https://doi.org/10.1145/3397617.3398033>
 - [51] Martin Fowler. 2015. Language Workbenches: The Killer-App for Domain Specific Languages? <https://www.martinfowler.com/articles/languageWorkbench.html>. [Online, accessed 11 August 2021].
 - [52] Christoph Frädich, Florian Obermüller, Nina Körber, Ute Heuer, and Gordon Fraser. 2020. Common Bugs in Scratch Programs. In *Proceedings of the 2020 ACM Conference on Innovation and Technology in Computer Science Education (Trondheim, Norway) (ITICSE '20)*. ACM, New York, NY, USA, 89–95. <https://doi.org/10.1145/3341525.3387389>
 - [53] D. Franklin, C. Hill, H. A. Dwyer, A. K. Hansen, A. Iveland, and D. B. Harlow. 2016. Initialization in Scratch: Seeking Knowledge Transfer. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education (Memphis, Tennessee, USA) (SIGCSE '16)*. ACM, New York, NY, USA, 217–222. <https://doi.org/10.1145/2839509.2844569>
 - [54] Terrell Glenn, Ananya Ipsita, Caleb Carithers, Kylie Peppler, and Karthik Ramani. 2020. StoryMakAR: Bringing Stories to Life With An Augmented Reality & Physical Prototyping Toolkit for Youth. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (Honolulu, HI, USA) (CHI '20)*. ACM, New York, NY, USA, 1–14. <https://doi.org/10.1145/3313831.3376790>
 - [55] G. Gome, J. Waksberg, A. Grishko, I. Y. Wald, and O. Zuckerman. 2019. OpenLH: Open Liquid-Handling System for Creative Experimentation with Biology. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction (Tempe, Arizona, USA) (TEI '19)*. ACM, 55–64. <https://doi.org/10.1145/3294109.3295619>
 - [56] Judith Good and Kate Howland. 2017. Programming language, natural language? Supporting the diverse computational activities of novice programmers. *Journal of Visual Languages & Computing* 39 (2017), 78–92. <https://doi.org/10.1016/j.jvlc.2016.10.008> Special Issue on Programming and Modelling Tools.
 - [57] Google. 2021. *Custom Blocks: Block Paradigms*. <https://bit.ly/37O143q>
 - [58] Jamie Gorson, Nikita Patel, Elham Beheshti, Brian Magerko, and Michael Horn. 2017. TunePad: Computational Thinking Through Sound Composition. In *Proceedings of the 2017 Conference on Interaction Design and Children (Stanford, California, USA) (IDC '17)*. ACM, New York, NY, USA, 484–489. <https://doi.org/10.1145/3078072.3084313>
 - [59] Andreas Grillenberger and Ralf Romeike. 2017. Real-Time Data Analyses in Secondary Schools Using a Block-Based Programming Language. In *Informatics in Schools: Focus on Learning Programming*, Valentina Dagienė and Arto Hellas (Eds.). Springer International Publishing, Cham, 207–218.
 - [60] Marianthi Grizioti and Chronis Kynigos. 2018. Game Modding for Computational Thinking: An Integrated Design Approach. In *Proceedings of the 17th ACM Conference on Interaction Design and Children (Trondheim, Norway) (IDC '18)*. ACM, New York, NY, USA, 687–692. <https://doi.org/10.1145/3202185.3210800>
 - [61] F. Hermans and E. Aivaloglou. 2016. Do code smells hamper novice programming? A controlled experiment on Scratch programs. In *2016 IEEE 24th International Conference on Program Comprehension (ICPC)*. 1–10. <https://doi.org/10.1109/ICPC.2016.7503706>
 - [62] Bryan Hernandez-Cuevas, William Egbert, Andre Denham, Ajay Mehul, and Chris S. Crawford. 2020. Changing Minds: Exploring Brain-Computer Interface Experiences with High School Students. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (Honolulu, HI, USA) (CHI EA '20)*. ACM, New York, NY, USA, 1–10. <https://doi.org/10.1145/3334480.3382981>
 - [63] C. Hill, H. A. Dwyer, T. Martinez, D. Harlow, and D. Franklin. 2015. Floors and Flexibility: Designing a Programming Environment for 4Th-6th Grade Classrooms. In *Proceedings of the 46th ACM Technical Symposium on Computer Science Education (Kansas City, Missouri, USA) (SIGCSE '15)*. ACM, 546–551. <https://doi.org/10.1145/2676723.2677275>
 - [64] R. Holwerda and F. Hermans. 2018. A Usability Analysis of Blocks-based Programming Editors using Cognitive Dimensions. In *2018 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 217–225. <https://doi.org/10.1109/VLHCC.2018.8506483>
 - [65] S. Hsu, Y. Lou, S. Jung, and C. Sun. 2017. Shelves: A User-Defined Block Management Tool for Visual Programming Languages. In *Human-Computer Interaction – INTERACT 2017*. Springer International Publishing, Cham, 335–344.
 - [66] IFTTT. 2021. IFTTT. <https://ifttt.com> [Online, accessed 03 January 2021].
 - [67] A. Islam, T. I. Rouf Uday, N. Ahmad, M. T. Islam, A. Ghosh, S. Kamal, T. Ahommed, M. Islam Leon, and E. A. Dhruvo. 2019. EduBot: An Educational Robot for Underprivileged Children. In *2019 International Conference on Automation, Computational and Technology Management (ICACTM)*. 232–236. <https://doi.org/10.1109/ICACTM.2019.8776756>

- [68] K. Ito. 2020. Work in Progress: Block Pictogramming A Block-based Programming Learning Environment through Pictogram Content Creation. In *2020 IEEE Global Engineering Education Conference (EDUCON)*. 1669–1673. <https://doi.org/10.1109/EDUCON45650.2020.9125386>
- [69] B. Jansen and F. Hermans. 2019. XLBlocks: a Block-based Formula Editor for Spreadsheet Formulas. In *2019 IEEE Symposium on Visual Languages and Human-Centric Computing*. 55–63. <https://doi.org/10.1109/VLHCC.2019.8818748>
- [70] S. Jatzlau, T. Michaeli, S. Seegerer, and R. Romeike. 2019. It’s not Magic After All – Machine Learning in Snap! using Reinforcement Learning. In *IEEE Blocks and Beyond Workshop*. 37–41. <https://doi.org/10.1109/BB48857.2019.8941208>
- [71] S. Jatzlau, S. Seegerer, and R. Romeike. 2019. The Five Million Piece Puzzle: Finding Answers in 500,000 Snap!-Projects. In *IEEE Blocks and Beyond Workshop*. 73–77. <https://doi.org/10.1109/BB48857.2019.8941206>
- [72] I. Jung, J. Choi, I. Kim, and C. Choi. 2016. Interactive learning environment for practical programming language based on web service. In *2016 15th International Conference on Information Technology Based Higher Education and Training (ITHET)*. 1–7. <https://doi.org/10.1109/ITHET.2016.7760705>
- [73] Kyo Kang, Sholom Cohen, James Hess, William Novak, and A. Spencer Peterson. 1990. *Feature-Oriented Domain Analysis (FODA) Feasibility Study*. Technical Report CMU/SEI-90-TR-021. Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA. <http://resources.sei.cmu.edu/library/asset-view.cfm?AssetID=11231>
- [74] K. Katchapakirin and C. Anutariya. 2018. An Architectural Design of ScratchThAI: A Conversational Agent for Computational Thinking Development Using Scratch. In *Proceedings of the 10th International Conference on Advances in Information Technology (Bangkok, Thailand) (IAIT 2018)*. ACM, NY, USA, 7. <https://doi.org/10.1145/3291280.3291787>
- [75] Annie Kelly, Lila Finch, Monica Bolles, and R. Benjamin Shapiro. 2018. BlocklyTalky: New programmable tools to enable students’ learning networks. *International Journal of Child-Computer Interaction* 18 (2018), 8–18. <https://doi.org/10.1016/j.ijcci.2018.03.004>
- [76] Annie Kelly, R. Benjamin Shapiro, Jonathan de Halleux, and Thomas Ball. 2018. ARcadia: A Rapid Prototyping Platform for Real-time Tangible Interfaces. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (Montreal QC, Canada) (CHI ’18)*. ACM, New York, NY, USA, 409:1–409:8. <https://doi.org/10.1145/3173574.3173983>
- [77] Daehoon Kim, Jaewoong Choi, In-Ho Jung, and Changbeom Choi. 2018. Pedagogy of Programming Education for Higher Education Using Block Based Programming Environment. In *Design, User Experience, and Usability: Designing Interactions*, Aaron Marcus and Wentao Wang (Eds.). Springer International Publishing, Cham, 39–50.
- [78] Barbara Kitchenham, O. Pearl Brereton, David Budgen, Mark Turner, John Bailey, and Stephen Linkman. 2009. Systematic literature reviews in software engineering – A systematic literature review. *Information and Software Technology* 51, 1 (2009), 7–15. <https://doi.org/10.1016/j.infsof.2008.09.009>
- [79] Barbara Ann Kitchenham and Stuart Charters. 2007. *Guidelines for performing Systematic Literature Reviews in Software Engineering*. Technical Report EBSE 2007-001. Keele University and Durham University Joint Report. https://www.elsevier.com/_data/promis_misc/525444systematicreviewsguide.pdf
- [80] W. Koehler and Y. Jing. 2018. A Novel Block-Based Programming Framework for Non-programmers to Validate PLC Based Machine Tools for Automotive Manufacturing Facilities. In *2018 11th International Conference on Developments in eSystems Engineering (DeSE)*. 202–207. <https://doi.org/10.1109/DeSE.2018.00046>
- [81] Michael Kölling, Neil C. C. Brown, and Amjad Altadmri. 2015. Frame-Based Editing: Easing the Transition from Blocks to Text-Based Programming. In *Proceedings of the Workshop in Primary and Secondary Computing Education (London, United Kingdom) (WiPSCE ’15)*. ACM, New York, NY, USA, 29–38. <https://doi.org/10.1145/2818314.2818331>
- [82] Michael Kölling, Neil C. C. Brown, Hamza Hamza, and Davin McCall. 2019. Stride in BlueJ – Computing for All in an Educational IDE. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education (Minneapolis, MN, USA) (SIGCSE ’19)*. ACM, New York, NY, USA, 63–69. <https://doi.org/10.1145/3287324.3287462>
- [83] Siu-Cheung Kong. 2019. *Learning Composite and Prime Numbers Through Developing an App: An Example of Computational Thinking Development Through Primary Mathematics Learning*. Springer Singapore, Singapore, 145–166. https://doi.org/10.1007/978-981-13-6528-7_9
- [84] Chonnuttida Koracharkornradt. 2017. Tuk Tuk: A Block-Based Programming Game. In *Proceedings of the 2017 Conference on Interaction Design and Children (Stanford, California, USA) (IDC ’17)*. ACM, New York, NY, USA, 725–728. <https://doi.org/10.1145/3078072.3091990>
- [85] Varsha Koushik, Darren Guinness, and Shaun K. Kane. 2019. StoryBlocks: A Tangible Programming Game To Create Accessible Audio Stories. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (Glasgow, Scotland Uk) (CHI ’19)*. ACM, New York, NY, USA, Article 492, 12 pages. <https://doi.org/10.1145/3290605.3300722>
- [86] Josiah Krutz, Harvey Siy, Brian Dorn, and Briana B. Morrison. 2019. Stepwise Refinement in Block-Based Programming. *J. Comput. Sci. Coll.* 35, 5 (Oct. 2019), 91–100.
- [87] A. Kurihara, A. Sasaki, K. Wakita, and H. Hosobe. 2015. A Programming Environment for Visual Block-Based Domain-Specific Languages. *Procedia Computer Science* 62 (2015), 287–296. <https://doi.org/10.1016/j.procs.2015.08.452>
- [88] C. Kyfionidis, N. Moumoutzis, and S. Christodoulakis. 2017. Block-C: A block-based programming teaching tool to facilitate introductory C programming courses. In *2017 IEEE Global Engineering Education Conference (EDUCON)*. 570–579. <https://doi.org/10.1109/EDUCON.2017.7942903>
- [89] J. Richard Landis and Gary G. Koch. 1977. The Measurement of Observer Agreement for Categorical Data. *Biometrics* 33, 1 (1977), 159–174. <http://www.jstor.org/stable/2529310>
- [90] Ž. Leber, M. Črepinek, and T. Kosar. 2019. Simultaneous multiple representation editing environment for primary school education. In *2019 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 175–179. <https://doi.org/10.1109/VLHCC.2019.8818927>

- [91] Á. Lédeczi, M. MarÓti, H. Zare, B. Yett, N. Hutchins, B. Broll, P. Völgyesi, M. B. Smith, T. Darrah, M. Metelko, X. Koutsoukos, and G. Biswas. 2019. Teaching Cybersecurity with Networked Robots. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (Minneapolis, MN, USA) (*SIGCSE '19*). ACM, New York, NY, USA, 885–891. <https://doi.org/10.1145/3287324.3287450>
- [92] Beng Yong Lee, Lee Hung Liew, Mohd Yazid Bin Mohd Anas Khan, and Azlina Narawi. 2020. The Effectiveness of Using MBot to Increase the Interest and Basic Knowledge in Programming and Robotic among Children of Age 13. In *Proceedings of the 2020 The 6th International Conference on E-Business and Applications* (Kuala Lumpur, Malaysia) (*ICEBA 2020*). ACM, New York, NY, USA, 105–110. <https://doi.org/10.1145/3387263.3387275>
- [93] Lap-Kei Lee, Tsz-Kin Cheung, Lok-Tin Ho, Wai-Hang Yiu, and Nga-In Wu. 2019. Learning Computational Thinking Through Gamification and Collaborative Learning. In *Blended Learning: Educational Innovation for Personalized Learning*. Springer International Publishing, Cham, 339–349.
- [94] Sorin Lerner, Stephen R. Foster, and William G. Griswold. 2015. Polymorphic Blocks: Formalism-Inspired UI for Structured Connectors. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) (*CHI '15*). ACM, New York, NY, USA, 3063–3072. <https://doi.org/10.1145/2702123.2702302>
- [95] N. Lytle, J. Echavarria, J. Sosa, and T. W. Price. 2019. Resource Rush: Towards An Open-Ended Programming Game. In *IEEE Blocks and Beyond Workshop*. 91–93. <https://doi.org/10.1109/BB48857.2019.8941215>
- [96] Jason Madar. 2019. c3d.io: Enabling STEAM (Science, Technology, Engineering, Arts, Mathematics) Education with Virtual Reality. In *Intelligent Computing*. Springer International Publishing, Cham, 1380–1386.
- [97] S. Marwan, J. Jay Williams, and T. Price. 2019. An Evaluation of the Impact of Automated Programming Hints on Performance and Learning. In *Proceedings of the 2019 ACM Conference on International Computing Education Research* (Toronto ON, Canada) (*ICER '19*). ACM, New York, NY, USA, 61–70. <https://doi.org/10.1145/3291279.3339420>
- [98] Monica M. McGill and Adrienne Decker. 2020. Construction of a Taxonomy for Tools, Languages, and Environments across Computing Education. In *Proceedings of the 2020 ACM Conference on International Computing Education Research* (Virtual Event, New Zealand) (*ICER '20*). ACM, New York, NY, USA, 124–135. <https://doi.org/10.1145/3372782.3406258>
- [99] A. Mehul, N. Cioli, C. S. Crawford, and A. Denham. 2019. Position: A Novice Oriented Dual-Modality Programming Tool for Brain-Computer Interfaces Application Development. In *2019 IEEE Blocks and Beyond Workshop*. 27–30. <https://doi.org/10.1109/BB48857.2019.8941226>
- [100] A. Milliken, V. Cateté, A. Isvik, and T. Barnes. 2020. Poster: Designing GradeSnap for Block-Based Code. In *IEEE Symposium on Visual Languages and Human-Centric Computing*. <https://doi.org/10.1109/VL/HCC50065.2020.9127284>
- [101] L. R. Milne and R. E. Ladner. 2018. Blocks4All: Overcoming Accessibility Barriers to Blocks Programming for Children with Visual Impairments. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) (*CHI '18*). ACM, New York, NY, USA, Article 69, 10 pages. <https://doi.org/10.1145/3173574.3173643>
- [102] L. R. Milne and R. E. Ladner. 2019. Position: Accessible Block-Based Programming: Why and How. In *IEEE Blocks and Beyond Workshop*. 19–22. <https://doi.org/10.1109/BB48857.2019.8941230>
- [103] Monika Mladenović, Ivica Boljat, and Žana Žanko. 2018. Comparing loops misconceptions in block-based and text-based programming languages at the K-12 level. *Education and Information Technologies* 23, 4 (01 July 2018), 1483–1500. <https://doi.org/10.1007/s10639-017-9673-3>
- [104] L. Moors, A. Luxton-Reilly, and P. Denny. 2018. Transitioning from Block-Based to Text-Based Programming Languages. In *2018 International Conference on Learning and Teaching in Computing and Engineering (LaTICE)*. 57–64. <https://doi.org/10.1109/LaTICE.2018.000-5>
- [105] Luke Moors and Robert Sheehan. 2017. Aiding the Transition from Novice to Traditional Programming Environments. In *Proceedings of the 2017 Conference on Interaction Design and Children* (Stanford, California, USA) (*IDC '17*). ACM, New York, NY, USA, 509–514. <https://doi.org/10.1145/3078072.3084317>
- [106] J. M. Mota, I. Ruiz-Rube, J. M. Dodero, and I. Arnedillo-Sánchez. 2018. Augmented reality mobile app development for all. *Computers & Electrical Engineering* 65 (2018), 250–260. <https://doi.org/10.1016/j.compeleceng.2017.08.025>
- [107] J. M. Mota, I. Ruiz-Rube, J. M. Dodero, T. Person, and I. Arnedillo-Sánchez. 2018. *Learning Analytics in Mobile Applications Based on Multimodal Interaction*. Springer, Cham, 67–92. https://doi.org/10.1007/978-3-319-68318-8_4
- [108] M. Müller, C. Schindler, K. K. Luhana, and W. Slany. 2018. Enabling Teenagers to Create and Share Apps. In *2018 IEEE Conference on Open Systems (ICOS)*. 25–30. <https://doi.org/10.1109/ICOS.2018.8632815>
- [109] H. Nergaard, N. Ulltveit-Moe, and T. Gjøsæter. 2015. A scratch-based graphical policy editor for XACML. In *2015 International Conference on Information Systems Security and Privacy (ICISSP)*. 1–9.
- [110] Henrik Nergaard, Nils Ulltveit-Moe, and Terje Gjøsæter. 2015. ViSPE: A Graphical Policy Editor for XACML. In *Information Systems Security and Privacy*. Springer International Publishing, Cham, 107–121.
- [111] Jacqueline Shao Yi Ong, Nana Adwoa O. Amoah, Alison E. Garrett-Engle, Mariella Irene Page, Katherine R. McCarthy, and Lauren R. Milne. 2019. Demo: Expanding Blocks4All with Variables and Functions. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility* (Pittsburgh, PA, USA) (*ASSETS '19*). ACM, New York, NY, USA, 645–647. <https://doi.org/10.1145/3308561.3354588>
- [112] Jesper Öqvist and Görel Hedin. 2017. Concurrent Circular Reference Attribute Grammars. In *Proceedings of the 10th ACM SIGPLAN International Conference on Software Language Engineering* (Vancouver, BC, Canada) (*SLE 2017*). Association for Computing Machinery, New York, NY, USA, 151–162. <https://doi.org/10.1145/3136014.3136032>
- [113] Terence Parr. 2013. *The Definitive ANTLR 4 Reference* (2nd ed.). Pragmatic Bookshelf.
- [114] Evan W. Patton, Michael Tissenbaum, and Farzeen Harunani. 2019. *MIT App Inventor: Objectives, Design, and Development*. Springer Singapore, Singapore, 31–49. https://doi.org/10.1007/978-981-13-6528-7_3

- [115] Klint Paul, Storm Tijs van der, and Vinju Jurgen. 2009. RASCAL: A Domain Specific Language for Source Code Analysis and Manipulation. (2009), 168–177. <https://doi.org/10.1109/SCAM.2009.28>
- [116] Carlos Pereira. 2021. *Ardublockly - Visual Programming for Arduino*. <https://ardublockly.embeddedlog.com/index.html>
- [117] Nicolai Pöhner, Timo Schmidt, André Greubel, Martin Hennecke, and Matthias Ehmman. 2019. BlocklySQL: A New Block-Based Editor for SQL. In *Proceedings of the 14th Workshop in Primary and Secondary Computing Education* (Glasgow, Scotland, UK). ACM, New York, NY, USA, Article 4, 2 pages. <https://doi.org/10.1145/3361721.3362104>
- [118] T. W. Price and T. Barnes. 2015. Comparing Textual and Block Interfaces in a Novice Programming Environment. In *Proceedings of the Eleventh Annual International Conference on International Computing Education Research* (Omaha, Nebraska, USA) (ICER '15). ACM, New York, NY, USA, 91–99. <https://doi.org/10.1145/2787622.2787712>
- [119] Thomas W. Price, Yihuan Dong, and Dragan Lipovac. 2017. ISnap: Towards Intelligent Tutoring in Novice Programming Environments. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education* (Seattle, Washington, USA) (SIGCSE '17). ACM, New York, NY, USA, 483–488. <https://doi.org/10.1145/3017680.3017762>
- [120] T. W. Price, R. Zhi, and T. Barnes. 2017. Hint Generation Under Uncertainty: The Effect of Hint Quality on Help-Seeking Behavior. In *Artificial Intelligence in Education*. Springer, Cham, 311–322.
- [121] A. Reinhardt, A. C. Esteban, J. Urbanska, M. McPhee, T. Greene, A. Duarte, B. Malheiro, C. Ribeiro, F. Ferreira, M. F. Silva, P. Ferreira, and P. Guedes. 2017. Didactic Robotic Fish – An EPS@ISEP 2016 Project. In *Interactive Collaborative Learning*. Springer International Publishing, Cham, 239–253.
- [122] G. Robles, J. Moreno-León, E. Aivaloglou, and F. Hermans. 2017. Software clones in scratch projects: on the presence of copy-and-paste in computational thinking learning. In *2017 IEEE 11th International Workshop on Software Clones (IWSC)*. 1–7. <https://doi.org/10.1109/IWSC.2017.7880506>
- [123] F. J. Rodriguez, C. R. Smith, A. Smith, K. E. Boyer, E. N. Wiebe, B. W. Mott, and J. C. Lester. 2019. Toward a Responsive Interface to Support Novices in Block-Based Programming. In *2019 IEEE Blocks and Beyond Workshop*. 9–13. <https://doi.org/10.1109/BB48857.2019.8941205>
- [124] R V Roque. 2007. OpenBlocks: an extendable framework for graphical block programming systems. (2007). <http://hdl.handle.net/1721.1/41550>
- [125] Simon P. Rose, M.P. Jacob Habgood, and Tim Jay. 2019. Using Pirate Plunder to Develop Children’s Abstraction Skills in Scratch. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland UK) (CHI EA '19). ACM, New York, NY, USA, Article LBW0172, 6 pages. <https://doi.org/10.1145/3290607.3312871>
- [126] Daniel Rough and Aaron Quigley. 2019. Challenges of Traditional Usability Evaluation in End-User Development. In *End-User Development*. Springer International Publishing, Cham, 1–17.
- [127] D. J. Rough and A. Quigley. 2020. End-User Development of Experience Sampling Smartphone Apps -Recommendations and Requirements. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 4, 2, 19. <https://doi.org/10.1145/3397307>
- [128] Dashley K. Rouwendal van Schijndel, Audun Stolpe, and Jo E. Hannay. 2020. Using Block-Based Programming and Sunburst Branching to Plan and Generate Crisis Training Simulations. In *HCI International 2020 - Posters*, Constantine Stephanidis and Margherita Antona (Eds.). Springer International Publishing, Cham, 463–471.
- [129] J. Saba, H. Hel-Or, and S. T. Levy. 2020. When is the Pressure Zero inside a Container? Mission Impossible: 7th Grade Students Learn Science by Constructing Computational Models Using the Much.Matter.in.Motion Platform. In *Proceedings of the Interaction Design and Children Conference* (London, United Kingdom) (IDC '20). ACM, New York, NY, USA, 293–298. <https://doi.org/10.1145/3392063.3394442>
- [130] A. Saini, K. Mathur, A. Thukral, N. Singhal, and A. Parnami. 2019. Aesop: Authoring Engaging Digital Storytelling Experiences. In *The Adjunct Publication of the 32nd Annual ACM Symposium on User Interface Software and Technology* (New Orleans, LA, USA). ACM, 56–59. <https://doi.org/10.1145/3332167.3357114>
- [131] Henrique Reinaldo Sarmento, Cibele A. S. Reis, Vinicius Zaramella, Leonelo D. A. Almeida, and Cesar A. Tacla. 2015. Supporting the Development of Computational Thinking: A Robotic Platform Controlled by Smartphone. In *Learning and Collaboration Technologies*. Springer International Publishing, Cham, 124–135.
- [132] Anthony Savidis and Crystalia Savaki. 2020. Complete Block-Level Visual Debugger for Blockly. In *Human Systems Engineering and Design II*. Springer International Publishing, Cham, 286–292.
- [133] B. Selwyn-Smith, C. Anslo, M. Homer, and J. R. Wallace. 2019. Co-located Collaborative Block-Based Programming. In *2019 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 107–116. <https://doi.org/10.1109/VLHCC.2019.8818895>
- [134] Mazyar Seraj, Cornelia S. Grosse, Serge Autexier, and Rolf Drechsler. 2019. Smart Homes Programming: Development and Evaluation of an Educational Programming Application for Young Learners. In *Proceedings of the 18th ACM International Conference on Interaction Design and Children* (Boise, ID, USA) (IDC '19). ACM, New York, NY, USA, 146–152. <https://doi.org/10.1145/3311927.3323157>
- [135] T. Seyed, P. de Halleux, M. Moskal, J. Devine, J. Finney, S. Hodges, and T. Ball. 2019. MakerArcade: Using Gaming and Physical Computing for Playful Making, Learning, and Creativity. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland UK). ACM, 6. <https://doi.org/10.1145/3290607.3312809>
- [136] D. Shepherd, P. Francis, D. Weintrop, D. Franklin, B. Li, and A. Afzal. 2018. [Engineering Paper] An IDE for Easy Programming of Simple Robotics Tasks. In *2018 IEEE 18th International Working Conference on Source Code Analysis and Manipulation (SCAM)*. 209–214. <https://doi.org/10.1109/SCAM.2018.00032>
- [137] Yasin N. Silva and Jaime Chon. 2015. DBSnap: Learning Database Queries by Snapping Blocks. In *Proceedings of the 46th ACM Technical Symposium on Computer Science Education* (Kansas City, Missouri, USA) (SIGCSE '15). ACM, New York, NY, USA, 179–184. <https://doi.org/10.1145/2676723.2677220>

- [138] Y. N. Silva, A. Nieuwenhuyse, T. G. Schenk, and A. Symons. 2018. DBSnap++: Creating Data-driven Programs by Snapping Blocks. In *Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education* (Larnaca, Cyprus). ACM, New York, NY, USA, 170–175. <https://doi.org/10.1145/3197091.3197114>
- [139] C. Solomon, B. Harvey, K. Kahn, H. Lieberman, M. L. Miller, M. Minsky, A. Papert, and B. Silverman. 2020. History of Logo. *Proc. ACM Program. Lang.* 4, HOPL, Article 79 (June 2020), 66 pages. <https://doi.org/10.1145/3386329>
- [140] A. Stahlbauer, M. Kreis, and G. Fraser. 2019. Testing Scratch Programs Automatically. In *Proceedings of the 2019 27th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering* (Tallinn, Estonia). ACM, New York, NY, USA, 165–175. <https://doi.org/10.1145/3338906.3338910>
- [141] A. Stratton, C. Bates, and A. Dearden. 2017. Quando: Enabling Museum and Art Gallery Practitioners to Develop Interactive Digital Exhibits. In *End-User Development*. Springer International Publishing, Cham, 100–107.
- [142] Glenn Strong, Sean O’Carroll, and Nina Bresnihan. 2018. A Block Based Editor for Python. In *Proceedings of the 13th Workshop in Primary and Secondary Computing Education* (Potsdam, Germany) (WiPSCE ’18). ACM, New York, NY, USA, Article 30, 2 pages. <https://doi.org/10.1145/3265757.3265788>
- [143] C. J. Sutherland and B. A. MacDonald. 2018. NaoBlocks: A Case Study of Developing a Children’s Robot Programming Environment. In *International Conference on Ubiquitous Robots*. 431–436. <https://doi.org/10.1109/URAI.2018.8441843>
- [144] R. Suzuki, T. Takahashi, K. Masuda, and I. Choh. 2018. Implementing Node-Link Interface into a Block-Based Visual Programming Language. In *Human-Computer Interaction. Interaction in Context*. Springer, Cham, 455–465.
- [145] A. Swidan, A. Serebrenik, and F. Hermans. 2017. How do Scratch Programmers Name Variables and Procedures?. In *2017 IEEE 17th International Working Conference on Source Code Analysis and Manipulation (SCAM)*. 51–60. <https://doi.org/10.1109/SCAM.2017.12>
- [146] A. G. Tamlas, T. J. Themelis, T. Karvounidis, Z. Garofalaki, and D. Kallergis. 2017. BSE: Blocks for rduino in the Students’ educational process. In *IEEE Global Engineering Education Conference*. <https://doi.org/10.1109/EDUCON.2017.7942956>
- [147] Karen Tatarian, Samuel Pereira, Micael S. Couceiro, and David Portugal. 2019. Tailoring a ROS Educational Programming Language Architecture. In *Robotics in Education*, Wilfried Lepuschitz, Munir Merdan, Gottfried Koppensteiner, Richard Balogh, and David Obdržálek (Eds.). Springer International Publishing, Cham, 217–229.
- [148] S. Taylor, W. Min, B. Mott, A. Emerson, A. Smith, E. Wiebe, and J. Lester. 2019. Position: IntelliBlox: A Toolkit for Integrating Block-Based Programming into Game-Based Learning Environments. In *IEEE Blocks and Beyond Workshop*. 55–58. <https://doi.org/10.1109/BB48857.2019.8941222>
- [149] P. Techapalokul and E. Tilevich. 2017. Understanding recurring quality problems and their impact on code sharing in block-based software. In *2017 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 43–51. <https://doi.org/10.1109/VLHCC.2017.8103449>
- [150] P. Techapalokul and E. Tilevich. 2019. Code Quality Improvement for All: Automated Refactoring for Scratch. In *2019 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. 117–125. <https://doi.org/10.1109/VLHCC.2019.8818950>
- [151] P. Techapalokul and E. Tilevich. 2019. Position: Manual Refactoring (by Novice Programmers) Considered Harmful. In *IEEE Blocks and Beyond Workshop*. 79–80. <https://doi.org/10.1109/BB48857.2019.8941201>
- [152] Marilyn Tenorio Melenje María, María Alejandra Trujillo, Julio Ariel Hurtado Alegría, and Cesar Collazos. 2019. Debugging Block-Based Programs. In *Human-Computer Interaction*. Springer International Publishing, Cham, 98–112.
- [153] F. Turbak, M. Sherman, F. Martin, D. Wolber, and S. C. Pokress. 2014. Events-first Programming in APP Inventor. *J. Comput. Sci. Coll.* 29, 6 (June 2014), 81–89. <http://dl.acm.org/citation.cfm?id=2602724.2602739>
- [154] T. Turchi, D. Fogli, and A. Malizia. 2019. Fostering computational thinking through collaborative game-based learning. *Multimedia Tools and Applications* 78, 10 (01 May 2019), 13649–13673. <https://doi.org/10.1007/s11042-019-7229-9>
- [155] T. Turchi, A. Malizia, and A. Dix. 2017. TAPAS: A tangible End-User Development tool supporting the repurposing of Pervasive Displays. *Journal of Visual Languages & Computing* 39 (2017), 66–77. <https://doi.org/10.1016/j.jvlc.2016.11.002> Special Issue on Programming and Modelling Tools.
- [156] Adilson Vahldick, António José Mendes, and Maria José Marcelino. 2017. Learning Analytics Model in a Casual Serious Game for Computer Programming Learning. In *Serious Games, Interaction and Simulation*, Carlos Vaz de Carvalho, Paula Escudeiro, and António Coelho (Eds.). Springer International Publishing, Cham, 36–44.
- [157] M. G. J. van den Brand, A. van Deursen, J. Heering, H. A. de Jong, M. de Jonge, T. Kuipers, P. Klint, L. Moonen, P. A. Olivier, J. Scheerder, J. J. Vinju, E. Visser, and J. Visser. 2001. The ASF+SDF Meta-Environment: A Component-Based Language Development Environment. In *International Conference on Compiler Construction*. Springer-Verlag, 365–370.
- [158] Mauricio Verano Merino and Tijs van der Storm. 2020. Block-Based Syntax from Context-Free Grammars. In *Proceedings of the 13th ACM SIGPLAN International Conference on Software Language Engineering* (Virtual, USA) (SLE 2020). ACM, New York, NY, USA, 283–295. <https://doi.org/10.1145/3426425.3426948>
- [159] R. Vinayakumar, K. Soman, and P. Menon. 2018. Alg-Design: Facilitates to Learn Algorithmic Thinking for Beginners. In *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. 1–6. <https://doi.org/10.1109/ICCCNT.2018.8493952>
- [160] R. Vinayakumar, K. Soman, and P. Menon. 2018. CT-Blocks: Learning Computational Thinking by Snapping Blocks. In *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. 1–7. <https://doi.org/10.1109/ICCCNT.2018.8493669>
- [161] R. Vinayakumar, K. Soman, and P. Menon. 2018. DB-Learn: Studying Relational Algebra Concepts by Snapping Blocks. In *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. 1–6. <https://doi.org/10.1109/ICCCNT.2018.8494181>

- [162] R. Vinayakumar, K. Soman, and P. Menon. 2018. Fractal Geometry: Enhancing Computational Thinking with MIT Scratch. In *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. 1–6. <https://doi.org/10.1109/ICCCNT.2018.8494172>
- [163] R. Vinayakumar, K. Soman, and P. Menon. 2018. Map-Blocks: Playing with Online Data and Infuse to Think in a Computational Way. In *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. 1–6. <https://doi.org/10.1109/ICCCNT.2018.8493700>
- [164] P. Voštinár. 2020. Programming LEGO EV3 in Microsoft MakeCode. In *2020 IEEE Global Engineering Education Conference (EDUCON)*. 1868–1872. <https://doi.org/10.1109/EDUCON45650.2020.9125170>
- [165] A. Wagh and U. Wilensky. 2018. EvoBuild: A Quickstart Toolkit for Programming Agent-Based Models of Evolutionary Processes. *Journal of Science Education and Technology* 27, 2 (01 April 2018). <https://doi.org/10.1007/s10956-017-9713-1>
- [166] W. Wang, R. Zhi, A. Milliken, N. Lytle, and T. W. Price. 2020. Crescendo: Engaging Students to Self-Paced Programming Practices. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education (Portland, OR, USA) (SIGCSE '20)*. ACM, New York, NY, USA, 859–865. <https://doi.org/10.1145/3328778.3366919>
- [167] David Weintrop. 2019. Block-based Programming in Computer Science Education. *Commun. ACM* 62, 8 (July 2019), 22–25. <https://doi.org/10.1145/3341221>
- [168] David Weintrop, Afsoon Afzal, Jean Salac, Patrick Francis, Boyang Li, David C. Shepherd, and Diana Franklin. 2018. Evaluating CoBlox: A Comparative Study of Robotics Programming Environments for Adult Novices. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (Montreal QC, Canada) (CHI '18)*. ACM, New York, NY, USA, Article 366, 12 pages. <https://doi.org/10.1145/3173574.3173940>
- [169] D. Weintrop, D. C. Shepherd, P. Francis, and D. Franklin. 2017. Blockly goes to work: Block-based programming for industrial robots. In *IEEE Blocks and Beyond Workshop*. 29–36. <https://doi.org/10.1109/BLOCKS.2017.8120406>
- [170] David Weintrop and Uri Wilensky. 2017. Between a Block and a Typeface: Designing and Evaluating Hybrid Programming Environments. In *Proceedings of the 2017 Conference on Interaction Design and Children (Stanford, California, USA) (IDC '17)*. ACM, New York, NY, USA, 183–192. <https://doi.org/10.1145/3078072.3079715>
- [171] D. Weintrop and U. Wilensky. 2018. How block-based, text-based, and hybrid block/text modalities shape novice programming practices. *International Journal of Child-Computer Interaction* 17 (2018), 83–92. <https://doi.org/10.1016/j.ijcci.2018.04.005>
- [172] David Weintrop and Uri Wilensky. 2019. Transitioning from introductory block-based and text-based environments to professional programming languages in high school computer science classrooms. *Computers & Education* 142 (2019), 103646. <https://doi.org/10.1016/j.compedu.2019.103646>
- [173] M. Wilkerson-Jerde, A. Wagh, and U. Wilenski. 2015. Balancing Curricular and Pedagogical Needs in Computational Construction Kits: Lessons From the DeltaTick Project. *Science Education* 99, 3 (2015). <https://doi.org/10.1002/sce.21157>
- [174] S. Xinogalos, M. Satratzemi, and C. Malliarakis. 2017. Microworlds, games, animations, mobile apps, puzzle editors and more: What is important for an introductory programming environment? *Education and Information Technologies* (2017). <https://doi.org/10.1007/s10639-015-9433-1>
- [175] Susan A. Yoon, Joeeun Shim, and Noora Noushad. 2019. Trade-Offs in Using Mobile Tools to Promote Scientific Action with Socioscientific Issues. *TechTrends* 63, 5 (01 Sept. 2019), 602–610. <https://doi.org/10.1007/s11528-019-00408-z>
- [176] S. Zhou, I. J. Livingston, M. Schiefsky, S. M. Shieber, and K. Z. Gajos. 2016. Ingenium: Engaging Novice Students with Latin Grammar. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (San Jose, California, USA)*. ACM, 944–956. <https://doi.org/10.1145/2858036.2858239>
- [177] A. Zimmermann-Niefeld, S. Polson, C. Moreno, and R. B. Shapiro. 2020. Youth Making Machine Learning Models for Gesture-Controlled Interactive Media. In *Proceedings of the Interaction Design and Children Conference (London, United Kingdom) (IDC '20)*. ACM, 63–74. <https://doi.org/10.1145/3392063.3394438>

A PHASE 2: FILTERING QUESTIONS

- Is the publication a full paper?
- Does the paper introduce a language or a tool that uses a block-based editor?
- Does the paper introduce a tool for building block-based environments?
- Does the paper use or study block-based environments?
- Does the paper present implementation details regarding the block-based environment?
- Does the paper present best practices for using block-based environments?
- Does the paper present best practices or guidelines for implementing block-based environments?
- Does the paper present limitations of block-based environments?
- Does the paper present open challenges that should be addressed with block-based environments?

B PROGRAMMING LANGUAGES POPULARITY

Language	Occurrences
Scratch	124
C	52
Java	50
Go	46
R	44
JavaScript	44
D	39
Python	35
Logo	28
Scheme	16
C++	15
SQL	9
NaN	8
PHP	6
Julia	6
Haskell	5
C#	3
Swift	3
TypeScript	3
LabVIEW	2
Scala	2
MATLAB	1
PL	1
Prolog	1
Visual Basic	1
Perl	1
Groovy	1
Lua	1
SAS	1
Ada	1

Table 22. pls popularity

C PAPERS PER VENUE

Venue	Category	# Papers
Human computer interaction	ACM Conference on Human Factors in Computing Systems (CHI)	13
	ACM Conference on Interaction Design and Children	11
	International Conference on Human-Computer Interaction (HCI)	4
	International Journal of Child-Computer Interaction	3
	Creativity and Cognition	1
	International Conference on Tangible, Embedded, and Embodied Interaction	1
	IFIP Conference on Human-Computer Interaction (INTERACT)	1
	ACM Symposium on User Interface Software and Technology (UIST)	1
	International Conference of Design, User Experience, and Usability (DUXU)	1
	International Symposium on End User Development	1
	Iberoamerican Workshop on Human-Computer Interaction (HCI-COLLAB)	1
	International Conference on Human Systems Engineering and Design: Future Trends and Applications (IHSED)	1
Programming / Human computer Interaction	IEEE Blocks and Beyond Workshop (Blocks and Beyond)	13
	IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)	9
	Journal of Visual Languages & Computing	2
	International Symposium on End User Development (IS-EUD)	2
Education	ACM Technical Symposium on Computer Science Education (SIGSE)	10
	IEEE Global Engineering Education Conference (EDUCON)	5
	Computational Thinking Education	2
	Education and Information Technologies	2
	Workshop in Primary and Secondary Computing Education	2
	International Conference on International Computing Education Research	2
	ACM Conference on International Computing Education Research	2
	ACM Transactions on Computing Education	1
	International Conference on Information Technology Based Higher Education and Training (ITHET)	1
	International Conference on Learning and Teaching in Computing and Engineering (LaTICE)	1
	Journal of Computing Sciences in Colleges	1
	Journal of computer sciences in colleges	1
	Innovation and Technology in Computer Science Education (ITICSE)	1
	Workshop in Primary and Secondary Computing Education (WIPSC)	1
	ACM Conference on Innovation and Technology in Computer Science Education	1
	International Journal of Artificial Intelligence in Education	1
	International Conference on Informatics in Schools: Situation, Evolution, and Perspectives (ISSEP)	1
	Computers & Education	1
	International Conference on Artificial Intelligence in Education (AIED)	1
	Journal of Science Education and Technology	1
	International Conference on Blended Learning (ICBL)	1
	International Conference on Computer Supported Education (CSEDU)	1
	International Conference on Interactive Collaborative Learning (ICL)	1
	International Conference on Learning and Collaboration Technologies (LCT)	1
	Software Data Engineering for Network eLearning Environments	1
Continued on next page		

Venue	Category	# Papers
Distributed computing	International Conference on Computing, Communication and Networking Technologies (ICCCNT)	5
	Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies	1
	IEEE International Smart Cities Conference (ISC2)	1
	IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW)	1
	Journal of Parallel and Distributed Computing	1
Robotics / Education	International Conference on Robotics and Education (RIE)	4
	Robotics in Education	1
Accessibility/ Human computer Interaction	ACM SIGACCESS Conference on Computers and Accessibility (ASSETS)	2
Programming	Science of Computer Programming	2
	ACM SIGPLAN International Conference on Systems, Programming, Languages, and Applications: Software for Humanity (Splash-E)	1
Security	International Conference on Information Systems Security and Privacy (ICISSP)	2
Software engineering	IEEE International Working Conference on Source Code Analysis and Manipulation (SCAM)	2
	IEEE International Conference on Program Comprehension (ICPC)	1
	ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering	1
	Conference of the Center for Advanced Studies on Collaborative Research (CASCON)	1
	IEEE International Workshop on Software Clones (IWSC)	1
	IEEE Transactions on Emerging Topics in Computing	1
	International Conference on Soft Computing and Software Engineering (SCSE'15)	1
	Journal of Systems Architecture	1
	IEEE Conference on Open Systems (ICOS)	1
Technology	International Conference on Advances in Information Technology	1
General	Communications of the ACM	1
	IEEE Access	1
	TechTrends	1
	Science and Information Conference (SAI)	1
Engineering	International Conference on Automation, Computational and Technology Management (ICACTM)	1
	International Conference on Developments in eSystems Engineering (DeSE)	1
Robotics	Iberian Robotics conference (Robot)	1
AI	International Conference on Ubiquitous Robots (UR)	1
	ITS (Intelligent Tutoring Systems) 2020	1
eBusiness	International Conference on E-Business and Applications (ICEBA)	1
Games	International Conference on Serious Games, Interaction, and Simulation (SGAMES)	1
Electrical engineering	Computers & Electrical Engineering	1
Multimedia	Multimedia Tools and Applications	1
Continued on next page		

D PAPERS PER COUNTRY

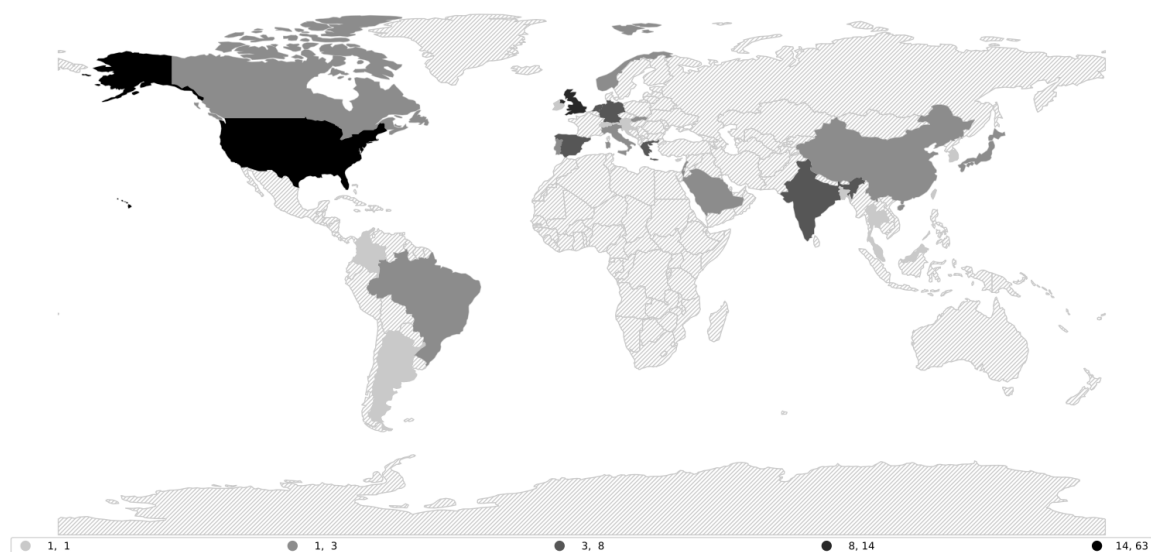


Fig. 7. This choropleth map displays a summary of the number of papers published per country. The detailed table with the values is shown in Table 24.

Country	Papers		
USA	64	Italy	2
UK	14	Slovakia	2
Germany	8	Thailand	1
Spain	6	Ireland	1
India	6	Malaysia	1
Greece	5	Scotland	1
Netherlands	5	Taiwan	1
New Zealand	4	Slovenia	1
Portugal	3	Bangladesh	1
Brazil	3	Argentina	1
Norway	3	Colombia	1
Japan	3	Croatia	1
Israel	3	South Korea	1
Canada	2	Korea	1
China	2	Austria	1
Saudi Arabia	2	Switzerland	1
Lebanon	2		

Table 24. Total number of papers included in this study per country

E POPULARITY PER TOOL ACROSS PUBLICATIONS

Name	Sum					
Scratch	127	BridgeTalk	2	TouchDevelop	1	
Blockly	59	Tern	2	Calico Jigsaw	1	
Alice	42	Ozobots	2	BlueJ	1	
Snap!	40	Waterbear	2	SPARQL	1	
App Inventor	40	Torino	2	Tickle	1	
Lego Mindstorms	23	Agentcubes	2	ScratchX	1	
PencilCode	13	mBlock	2	Flip	1	
GreenFoot	12	EvoBuild	2	Logo	1	
Makecode	11	UML	2	Code3	1	
GP	9	DataSnap	2	Snap4Arduino	1	
Tiled Grace	9	Ladder	2	E-Block	1	
Dr. Scratch	6	Kodu	2	RoboBlocks	1	
Code.org	6	Blockly@rduino	2	Microsoft Touch Develop	1	
Scratch Jr	6	Tynker	2	MicroApp	1	
Droplet	5	Frog Pond	2	Blockpy	1	
LogoBlocks	5	iSnap	2	AppLap	1	
PocketCode	5	LaPlaya	1	CustomPrograms	1	
Ardublockly	5	ITCH	1	Robobo	1	
StarLogo TNG	5	DBSnap	1	CodeSpells	1	
BYOB	4	BEESM	1	Turtle Art	1	
NetsBlox	4	CustomPrograms.1	1	Micropython	1	
Nettango	4	CodeIt	1	Sketchware	1	Visual AgenTalk 1
Blocks4All	4	CARMEN	1	Thunkable	1	Tica 1
Stencyl	4	Pixly	1	AppyBuilder	1	Blockly Turtle 0
CT-Blocks	4	BlockImpress	1	BLOX	1	Cognimates 0
Blocklyduino	4	Polymorphic Blocks	1	Finch robot	1	
BlockyTalky	4	ecraft2learn	1	App Inventor Java Bridge	1	
Hairball	4	Spherly	1	Robokol	1	
RoboBuilder	3	FabCode	1	BehaviourComposer	1	
pencil.cc	3	MakerArcade	1	AgentSheets	1	
Deltatick	3	MORPHA	1	TurtleArt	1	
DrawBridge	3	RoboBlockly	1	PicoBlocks	1	
Openblocks	3	edbot	1	Scratch Memories	1	
ArduBlock	3	NEPO	1	Scratch Community Blocks	1	
Modkit	3	Patch	1	PseudoBlocks	1	
Squeak eToys.	3	DStBlocks	1	OzoBlockly	1	
Bags	3	Neuroblock	1	TinkerBlocks	1	
Dash and dot	3	ROBOLAB	1	ViMAP	1	
Open roberta	3	Amphibian	1	KidSim	1	
Hopscotch	3	GradeSnap	1	Gameblox	1	
CoBlox	2	Accessible Blockly	1	Phratch	1	
Storyblocks	2	PopBots	1	Romo	1	
robot blockly	2	Quality Hound	1	N-Bot	1	
BlockEditor	2	Prime	1	Cherps	1	
SQLSnap	2	Pictogramming	1	Toon Talk	1	
		AliCe-VilLagE	1	StarLogoBlocksNova	1	

F PROGRAMMING LANGUAGES USED TO IMPLEMENT BLOCK-BASED ENVIRONMENTS

Programming language	Papers
N/A	100
JavaScript	15
HTML, JavaScript, and CSS	15
Java	3
Python	2
iOS (Swift)	2
JavaScript & Java	2
Pharo Smalltalk	2
TypeScript	2
AngularJS and TypeScript	1
Snap!	1
Python, HTML, CSS and Javascript	1
Java / JastAdd	1
Java / ANTLR	1
ActionScript	1
PHP-based framework & JavaScript and HTML5	1
Tiled Grace	1

Table 25. Programming languages used to implement block-based environments.

G TOOLS USED FOR DEVELOPMENT

Library	# of languages		
NaN	62		
Blockly	40		
Scratch	11		
Snap!	7		
Scratch 3.0 (Blockly)	3		
CT-Blocks	3	NetsBlox	1
App inventor & Blockly	2	PencilCode, Droplet	1
Microsoft MakeCode	2	Openblocks [124]	1
BlocklyDuino	2	Ardublock	1
Python	1	Tiled Grace	1
NetTango	1	Scratch & Blockly	1
Blockly@rduino	1	Snap! & DB Snap	1
Blockly and Standard pictogramming	1	App inventor	1
Nettango	1		
Blockly, Monaco, MakeCode	1		
iSnap [119]	1		
Droplet	1		
MakeCode	1		
Snap! & Scratch	1		
Deltatick	1		

Table 26. List of tools used for the development of block-based editors.

H DOMAINS

Sub-category	Category
End-user programming Parallel Programming Behavioural programming Audio programming Collaborative Programming Programming Programming Models	Programming
Education Parallel Programming education Computational Thinking Programming education socioscientific issues (SSI) education Grammar education Education programming Computer Science Education Simulation-based training Latin Parson problems	Education
Programming environments Novice programming environments Accessible Programming Environments Spreadsheets Block-based Environments Frame-based editing	Programming environments
Security Privacy	Security
Robotics Micro:bit Collaborative robots Embedded systems development Physical computing Microcontrollers Automotive manufacturing Smart cities Mobile	Physical computing
Scratch Visual DSLs Block-based languages	Languages
Augmented reality Human Robotics Interaction Usability Tangible surfaces Intelligent Tutoring Systems HCI Brain-Computer Interface Tangible user interfaces Brain-computer Interfaces end-user development	HCI

Sub-category	Category
Accessability	
Visualization	
Gaming	
Music	
Cultural Heritage (museums & art)	ARTS & Creativity
Tinkering	
Storytelling	
Biology	
Chemistry	Science
Medicine	
AI	
Data Science	
Data-driven programs	
Data Analysis	AI
data analysis and visualization	
Machine learning	
program analysis	
Code quality	
Testing	
Databases	Software Engineer
Static analysis	
program analysis and transformation	
Software quality	
Agent-based computational model	
Agent-based modelling	Agent-based model
Agent-based modelling tasks	