Towards a collaborative taxonomy of Tools, Languages and Environments in K-12 Computing Education

Agnese Addone
Department of Computer Science
University of Salerno
Fisciano, Italy
0000-0003-1170-8031

Vittorio Scarano
Department of Computer Science
University of Salerno
Fisciano, Italy
0000-0001-8437-5253

Carmine Spagnuolo
Department of Computer Science
University of Salerno
Fisciano, Italy
0000-0002-8267-9808

***Abstract*—In this Work-in-Progress paper we present a preliminary study and the design of a taxonomy of Tools, Languages and Environments (TLE) employed in K-12 Computing Education, in schools and outreach programs. The research provides an analytical classification model based on a survey of TLEs and on previous related works. It also outlines the collaborative protocol that will allow researchers to share the results of the taxonomy on a public repository. An analysis of the most common platforms where contributors can work collaboratively is presented to show the qualitative process of identification and choice of GitHub as the most reliable one.**

***Index Terms*—K-12, Outreach, Learning environment, Bloom's taxonomy, Rubric, Course assessment, Online repositories, User centered design, Computer Science.**

I. Introduction

The huge development of the research on K-12 Computing Education (CED) offers detailed studies on several aspects of this field, that is so crucial to social, economic and cultural progress in our society based on Information and Communication Technologies (ICT).

Teaching and learning Computer Science (CS) in schools or outreach settings are characterized by a triad of Tools, Languages and Environments (TLE) for K-12 Computing Education that increase daily. The demand and release of new instruments specifically intended for education and a K-12 target aims mainly to avoid novice students or their teachers the complexity of using professional programming environments [1]. One of the main problems in the design of a K-12 computing class or initiative is the selection of a particular tool that meets and satisfies the choice of a specific target, school order, social group audience, programming skill level or available infrastructure. It becomes indispensable to overcome the problems of use and to increase students' experience and motivation [2]. Educational TLEs represent crucial components in the design of K-12 computing initiatives. Given the variety and heterogeneity of available educational TLEs, researchers and educators face the challenge of identifying the best tool for the purpose they have set and they invest time and effort to determine which is the best one to realize it.

In this context, a classification of this broad field becomes essential to achieve common and univocal descriptions and definitions [3]. Researchers are used to exploit their own terminology of the TLEs, but it is crucial to avoid duplication of terms with synonyms and to guarantee common keywords [4] to obtain a reliable vocabulary and optimize the research strategy.

Our contribution - We aim to provide teachers, but also researchers, with a categorized and shared repository of TLEs employed in K-12 Computing Education programs to support the design of their courses, primarily based on the selected targets and audiences. The purpose is to avoid educators too much effort and possible failures in the choice, but also to guide a proper assessment of the initiatives. The hierarchy of the repository items, set by keywords, has the goal of building a TLEs taxonomy. It will benefit from the comparison of previous related studies on classifications and educational taxonomies.

The value of social construction of knowledge is the main aspect of our proposal. We have selected a platform for collaborative work [5], [6], in order to enhance collaborators' (teachers, educators, researchers) interaction in implementing the repository. It will also point to build a community where discussing and comparing the differences and issues related to the TLEs terminology in order to achieve a common vocabulary. The platform has a version control system to manage the items that avoids errors and duplications. In this paper we also provide a comparative analysis of the features of the collaborative tools that we have studied to make our final choice.

Currently, we have already classified a first survey of TLEs according to the methodology for constructing a taxonomy proposed in [3], and we are extending it daily. We selected tools already utilized in K-12 programs and recognized as effective in teaching or learning programming. To this group of TLEs, we added other tools of common use in the classroom and outreach, but not (yet) studied in the literature. Our idea is to provide teachers and scholars with a broader overview of the possible choices, according to the different learning contexts of programming and computational thinking.

II. Related works

Mainly inspired by the Taxonomy of Educational Objectives by Benjamin S. Bloom [7] and its revised version [8] as well, researchers use and adapt the classification methodology with their different approaches [9]–[12] to develop a suitable framework for K-12 Computing Education.

The design of Computing Education initiatives often begins with the choice of a single programming language or educational tool, or from the selection of a digital learning environment that can be accessible and reliable for a specific target audience or school level.

There are many studies that introduce analytical descriptions and make an evaluation on the use or impact of a TLE taxonomy in educational settings in relation to their goals [13]–[16]. Other papers collect information from the enacted CED experiments and offer some wider analysis by comparing a consistent group of TLEs. They generate very interesting classifications [1], [13], [17]–[19], also on single fields of the discipline. The researchers list and explain their characteristics, guiding the choice of using them in the design of different programs and in various educational contexts.

However, there is not a thorough taxonomy to define the whole landscape of Tools, Languages and Environments in K-12 Computing Education nor to level out the different terminology related to their classification.

A recent study [3] summarizes the state-of-the-art of research on taxonomies in primary and secondary Computing Education and proposes a method to generate a taxonomy by descending from other attempts traceable in the literature. We started by this accurate work, as it presents a methodology to align the taxonomies reported by a notable corpus of papers and suggests also a formal process to generate a coherent taxonomy.

III. Research questions

The literature on CED taxonomies highlights how broad is the field of TLEs and the difficulty to reach a common framework. Consequently, we will define our research according to three research questions, which we would like to investigate:

- RQ1 - What are the TLEs, since the release of LOGO until today?
- RQ2 - How to make a review of TLEs that are not covered in (scientific) literature but commonly used in K-12 CED?
- RQ3 - What features must a collaborative tool possess to ask the community to define a shared taxonomy of TLEs?

In RQ1 we considered LOGO as an ancestor of a big part of the current TLEs because of its importance in CED research and for its influence on a family of languages it has generated.

The review in RQ2 is necessary to achieve a significant number of TLEs, to compare and finally to adequately classify them. It is essential to include also those items not described in scientific literature but actually employed in schools or outreach settings, in spite of their lack of scientific evidence of effectiveness.

With RQ3 we aim to define the best platform for our taxonomy through a requirements comparison of the most common tools in use. The highest quality of the collaboration features and of the accessibility means is essential to guarantee the collaborators' participation and the version control.

IV. Our taxonomy

The classification originates from a literature survey of the TLEs in K-12 Computing Education that we made using the most common scholarly search engines. The survey was also extended to other items found through a wider web research and on the app stores for mobile devices, because they are often employed but not reviewed.

We collected TLEs that range from the Logo release until today and that we organized in a taxonomy ordered in 4 classes and 15 categories.

The Taxonomy Classes are: Languages, Microcontrollers; boards and robotics; Platforms/courses/MOOCS; Games and apps.

The Taxonomy Categories are: TLE name, Website URL; Release year; Release source - DOI; Lead researcher; Research/development team; Affiliation of the team; City; Country; Download; Paradigm; Purpose; Characteristics; Target/audience; Foundation; Community of support.

The classes express four groups of TLEs, i.e. programming languages with a main educational purpose, tangible/physical computing tools, platforms and environments for learning to program, educational games and mobile apps.

In the Class 1 we have included any language designed for educational use and for teaching/learning programming and computational thinking. Some languages support also physical devices or robotics kits, some others have multidisciplinary purposes, like teaching coding for generative arts or music.

In Class 2, the class of tangible or physical computing, we have collected tools like microcontrollers, single-board computers and educational robotics kits and tools.

Among platforms in Class 3, we have considered any environment where students and teachers can learn and experiment programming and computational thinking.

Finally, we grouped under Class 4 the educational games and mobile apps for learning to program while playing.

Every TLE is also analyzed according to its general description data as well as to a qualitative analysis of its features and educational purposes. The different categories encompass data on the research and development leader and team, the website URL and the type of download (free or paid). The classification includes also the programming paradigm of the TLE, the formative objectives and programming skills attended, the specific educational purpose, the existence of a possible common ancestor to establish its membership in a family of languages.

We have also identified and inserted in the taxonomy some aspects related to the social aspects of programming, such as the existence of a community of support and learning, and finally if the TLE is sponsored by any not-for-profit organization (like a Foundation).

V. Collaborative writing platforms

Designing and implementing in a collaborative manner the *K-12 Computing Education Taxonomy* pose a set of non-trivial challenges. These directly derive from the need to ensure the highest reliability and quality of the collected TLEs. To ease this process, we investigated existing collaborative tools and platforms to define the cooperation protocol and the presentation strategy of our taxonomy. We specifically considered the most adopted and popular online platforms for collaborative editing, visualizing/presenting, and uploading/downloading data. In our analysis, we examined the following requirements:

- *Easiness of use*: the platform should allow contributors to access and submit new records easily.
- *Automatic Presentation of the taxonomy*: the platform should enable the automatic generation of a rich presentation of the taxonomy at every newly added record.
- *Contributor Covenant*: the platform should support a code of conduct, which regulates the contributions to the TLE to ensure high reliability/quality of records.
- *Users Roles*: the platform should ensure different users' roles as admins, contributors, and viewers.
- *Accessibility*: the platform should provide accessibility from any device (desktop, mobile, etc.) for both editing and visualizing.

Table I compares the investigated platforms considering the above requirements.

Our solution. To implement our collaborative editing and presentation process, we finally chose the GitHub platform thanks to its support of contributor covenants and the possibility to personalize the presentation of data via website templates. Further, GitHub enabled us to design our contribution protocol using versioning control and the pull requests (PR) mechanism. PRs allow team members to be notified of contributions to the repository so that they know they can review the proposals. In other words, GitHub provides a forum for discussing the quality and reliability of PRs before being included in the central repository.

We will set up a GitHub repository providing the implementation of our collaborative contribution protocol and automatic presentation building process depicted in Figure 1. It consists of the following elements:

- a CSV file which collects and stores the contributions to the taxonomy to support versioning control;
- a code of conduct that defines standards for how to engage contributors in our community;
- a PR template, which allows contributors to submit changes to the CSV data taxonomy;
- the source code of our presentation site, written with the Jekyll [24] static site generator used by GitHub pages. Our presentation site will start from the taxonomy stored in the CSV data file and will produce an interactive and responsive website to explore, filter, and visualize them;
- a GitHub presentation site-building action, which will be triggered every time a PR is merged into the central repository and that generates an updated version of the presentation site based on the last version of the taxonomy.

As shown in Figure 1, our methodology comprises several initial cooperating editing steps (left side of the figures) based on versioning control of data and the PR mechanism for permitting the revision of the contributions by the *Admins* community. After the editing phase, the system automatically generates a new presentation site version for each accepted contribution (PR merge) via the GitHub action.

VI. Conclusions

In this paper we presented the design of a taxonomy of the TLEs adopted in K-12 Computing Education and the importance of a collaborative environment for its implementation.

We have analyzed comparatively a number of different tools meant for collaborative contribution and finally we gave evidence of the best features that the community can benefit of, based on quality, reliability and accessibility of the tools themselves.

Therefore we can summarize the answers to our RQs:

RQ1- The panorama of the TLEs since the release of LOGO is actually wide, however it is possible to gather and classify them. The *K-12 Computing Education Taxonomy* is the result of an analysis of their characteristics and it supports the definition of their value in the design and assessment of the CED programs, in schools or outreach.

RQ2- It can be hard for a single researcher to make a reliable and qualitative review of this vast catalogue. A collaborative tool, as a social platform, represents the most effective instrument for scholars and educators to participate, to share results and to amend errors. Online communities usually achieve great improvements in common knowledge and contribute to the advancement of research.

RQ3- Proper tools are essential while working collaboratively, and our previous comparative analysis suggests the most reliable platform for the presented taxonomy. The protocol needs very specific features, and we showed that each platform can really condition or instead allow contributors to participate and admins to manage the pull requests and supervise the version control protocol.

Future works - We intend to regularly collect the contributors' feedback during the collaborative participation in the taxonomy. A qualitative analysis of their comments is a start point to monitor the community engagement and in order to make significant improvements to the platform. We also aim to collect and link experiences from various educative contexts, a catalogue of good practices from worldwide educators, in order to provide further guidance to teachers and researchers of the community when choosing a TLE for their activities.

In conclusion, the *K-12 Computing Education Taxonomy* platform supports educators and scholars in identifying, defining, consulting, and implementing a catalogue of TLEs for classroom activities. It also contributes to review the TLEs commonly used in Computing Education but not analyzed in the scientific literature. It provides a reliable process of shared

TABLE I
LIST OF PLATFORMS AND TOOLS ANALYZED TO COLLABORATIVELY CONTRIBUTE TO THE K-12 COMPUTING EDUCATION TAXONOMY.

Name	Description	Easiness of use	Automatic Presentation	Contributor Covenant	Users Roles	Accessibility
Google Sheet [20]	Web application for collaborative online creation and update of spreadsheets through the Google Drive website.	*High*: collaborative by design.	*Low*: Table representation.	*No*	*Low*: Editors/Viewers	*High*: Cross-platform application.
Zenodo [21]	General-purpose open repository. It allows researchers to deposit research papers, data sets, research software, reports, and any other digital artifacts by accessing them using a DOI.	*Low*: No collaborative editing.	*Low*: Table representation.	*No*	*Low*: Publishers/ Viewers	*Medium*: Web responsive site.
MediaWiki [22]	Free and open-source server-based wiki software that allows the definition of static web pages using the wiki markup language.	*Medium*: Collaborative editing of files defined in Wiki markup language.	*Medium*: Wiki web pages.	*No*	*High*: Different users roles and groups.	*High*: Cross-platform application.
Notion [23]	All-in-one workspace where users can write, plan, collaborate, and get organized. Notion provides the building blocks for generating layouts and a toolkit in the form of "advanced wiki".	*Medium*: Collaborative editing of markdown files and platform specific blocks.	*Medium*: Different data blocks (representation).	*No*	*High*: Owners/Guests (with several access levels).	*High*: Cross-platform application.
GitHub [5]	Provider of Internet hosting for software development and version control using Git. GitHub also offers several other features, such as GitHub pages for building static websites and the definitions of actions, which are a piece of event-driven execution.	*Medium*: Distributed version control for any machine-readable data format.	*High*: GitHub pages [6]	*Yes*	*High*: Owners/ Contributors (with several access levels).	*High*: Cross-platform application.

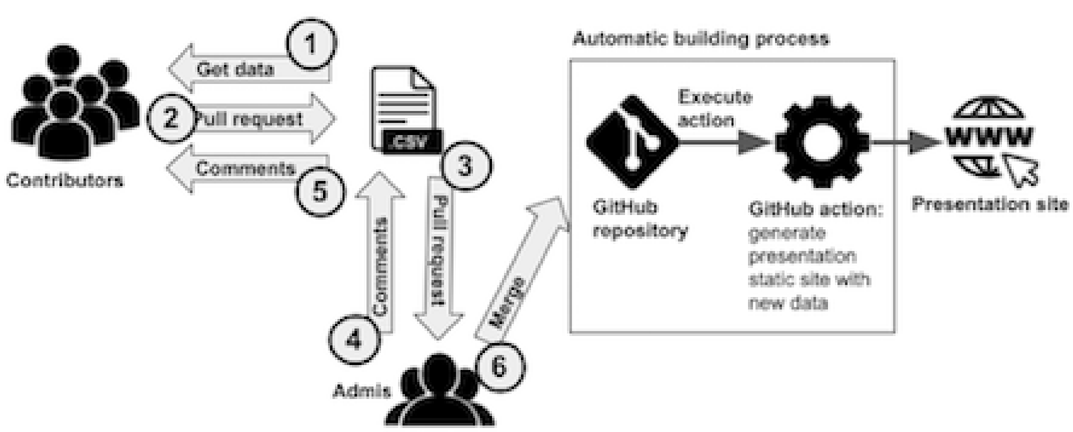

Fig. 1. The collaborative editing and building process of K-12 Computing Education Taxonomy.

classification and represents an accessible environment to enhance collaboration among researchers to add further findings. According to the principles and impact of Open Science [25], through our repository and taxonomy we intend to encourage collaboration within the community of researchers. The effort, ensured by the use of the GitHub platform and its features, will adopt the system of the pull requests and the version control updates. The results of the *K-12 Computing Education Taxonomy* will be publicly available under a Creative Common License 4.0 Share-alike.

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