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Abstract

The ever growing importance of computers and their use created a need for the teaching of computational thinking. In order to better analyze the learning process of the students, teachers and researches often resort to alternative ways of teaching and analysis like visual programming and learning trajectories. Learning trajectories are the steps or paths the students follow as they learn. The task of analyzing the learning trajectories falls upon the area of information visualization. This field of knowledge and research aims to present and extract meaning by creating visual representations of data, the so called visualizations. In this context, this work objective is to propose new literature based and interactive intensive visualizations to represent learning trajectories in order to further enhance the computational thinking learning process by helping teachers to analyze student's learning trajectories. A usability evaluation was conducted with the participation of 23 elementary school teachers and gathered their understanding and feedback in order to assess the usability, acceptance, effectiveness and expressiveness of the proposed visualizations with good overall results. This study contributions besides the proposed visualizations include a new way of organizing visualizations based on layers of representational and interaction aspects and the knowledge gathered about what seems to increase the effectiveness of the visualizations according to the educators perspective.

Key-words: Computational Thinking. Visual Programming. Visualization, Information Visualization, Learning Trajectories, Usability Evaluation.

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List of abbreviations and acronyms

CT   Computational Thinking

HCI   Human Computer Interaction

SAM   Self-Assessment Manikin

VLE   Virtual Learning Environment

Contents

1 Introduction

Information Visualization is an emerging scientific area with applications in many scientific fields. It aims to ease the process of obtaining and understanding information through visual analysis of data sets by users with the help of computational resources (NASCIMENTO; FERREIRA, 2005; SILVA, 2014).

The evolution of computers had great influence in several areas of science. With it's ever growing capacity of manipulate and analyze great data sets, explore and extract meanings, the utilization and teaching of computation became new fields of research and learning (RAABE et al., 2017).

Due to the integration of computation in the scientific process, in the development of other sciences and it's increasing importance as a science in itself, the computational teaching started to gain space in the curriculum of several schools (RICH et al., 2017; RAABE et al., 2017; RICH et al., 2018). In order to teach how to program computers teachers had to teach notions of abstractions beyond the physical dimensions of time and space (WING, 2008).This notions of abstractions are called Computational Thinking (CT). It is the capacity of analyze, systematize, represent and solve problems (RAABE et al., 2017), a kind of analytical thinking that shares with mathematical thinking the general ways in which one might approach solving a problem (WING, 2008).

Several countries like Germany, Argentina, Australia, South Korea, Scotland, France, England, United Estates of America, Finland, Greece, India, Israel, Japan and New Zealand, among others, started to teach computation in schools in order to develop abilities related to the comprehension and fluency in the digital word, as well as the resolution of complex problems (RAABE et al., 2017).

As new ways of working with the learning process of computational thinking arose, it became increasingly necessary to have an understanding of the key concepts that are essential to the learning process of the students (RICH et al., 2018; RICH et al., 2017; RAABE et al., 2017; WALDEN et al., 2013; MILLER et al., 2014).

In order to better understand this learning process and improve the ways the key concepts are taught, pushed by the ever growing necessity of an efficient teaching process of computational thinking, some professionals of the educational field started to look at the learning paths or learning trajectories. In a simplified manner, learning trajectories are possible paths that the students may follow in order to achieve their learning goals (FORTENBACHER et al., 2013; CAI, 2018; RICH et al., 2017; RICH et al., 2018; MILLER et al., 2014).

With the help of the learning trajectories and visualizations that can represent them, education professionals can have a better understanding of the learning progress and trajectories trailed by the students. In this context of learning trajectories, their representation by visualizations gains a lot of importance. Visualizations can be defined as the process of transforming something abstract in images in such a way that they can be viewed by human beings (NASCIMENTO; FERREIRA, 2005). Nascimento and Ferreira (2005) state that the goal of a visualization is to help in the understanding of a subject, which would require much more effort to be understood without a visualization. Through visual exploration researchers are able to extract meaning and knowledge and conclusions of the students learning process (NASCIMENTO; FERREIRA, 2005; KEIM, 2002; FORSELL, 2010).

1.1   Objectives

This master's project aim is to proposed new literature based visualizations of learning trajectories in the context of students learning computational thinking through visual programming. The visualizations were constructed using a novel layer system that distributes the data according to representation aspects and interaction. The proposed visualizations aim to aid teachers in the visual process of analyzing the learning trajectories of students.

With the collaboration of teachers working in elementary education I conducted a usability evaluation with the objective of analyzing the results and draw conclusions about the overall acceptance and usability of the proposed visualizations as well as identify possible improvements according to the participants reactions and feedback, while also analyzing the possible correlation that may exist between the evaluation results and the participants profiles.

1.2   Methodology

The methodology used can be seen at Figure 1 .

- A - Literature Review of relevant papers and studies in order to identify the current state of the art regarding visualization of learning trajectories

- B - Study of some of the existing tools for creating the visualizations. I chose D3[1] as the main tool for creating visualizations.

- C - Creation of the visualizations incorporating characteristics present on the literature with the aid of the Specialist Group UXLeris.

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[1]   <https://d3js.org/>
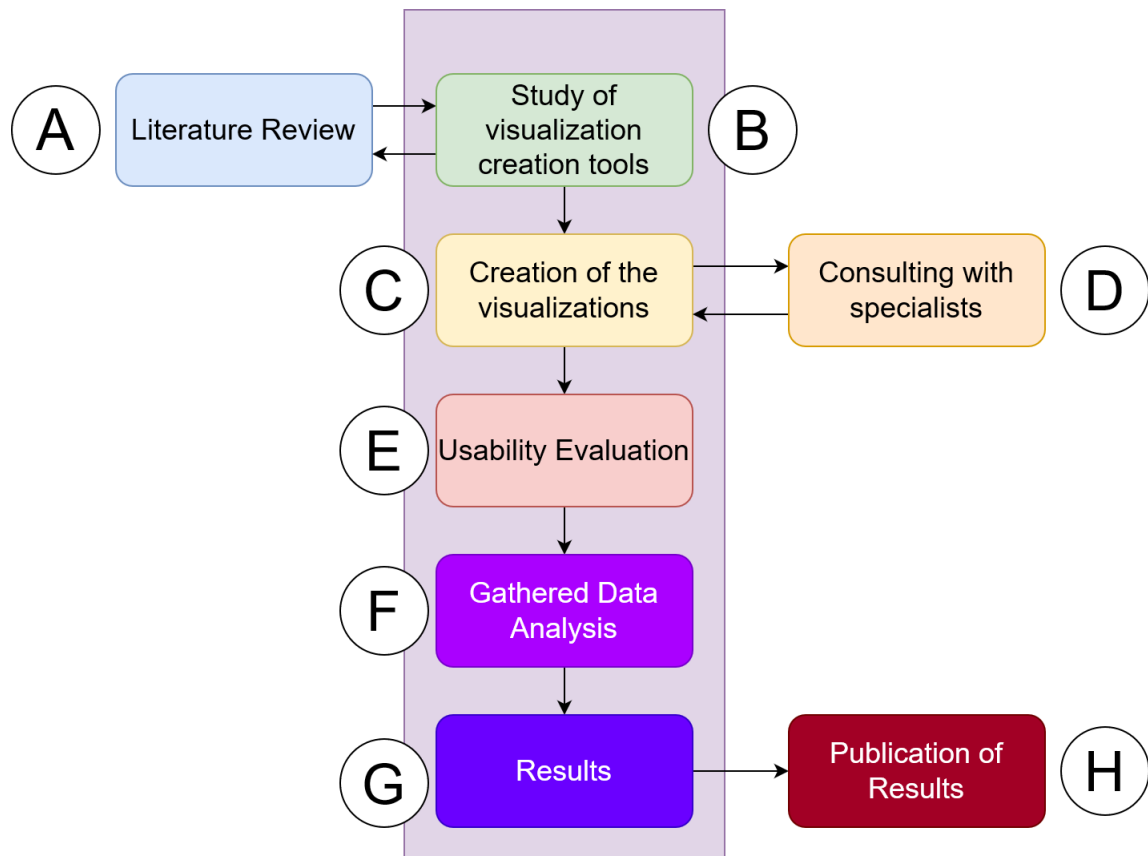
Figure 1 – Methodology

- D - Consulting in the form of focus group with specialists. This step was done a few times in order to hone the visual and interaction aspect of the proposed visualizations.

- E - Usability Evaluation with teachers working on the elementary schools.

- F - Analysis of the gathered data from the Usability evaluation. The emotional aspects were analyzed via Self Assessment Manikin (SAM) (BRADLEY; LANG, 1994) questionnaire as well as the general understanding of the visualizations while searching for correlations with profile characteristics of the participants.

- G - Results are presented here on a later section this work and includes results qualitative and quantitative analysis of the proposed visualizations and how well they were understood, as well as possible improvements and contributions of this work.

- H - The publication of the results including conclusions and discussion in the form of this dissertation and an article that will be submitted for publication.

1.3 Contributions

The main contributions of this work are:

- The proposed visualizations based on the available literature, aiming to improve the process of visual analysis of the students' learning trajectories.

- The classification of the visualization in different layers of visual and interaction aspects. Such division and description based on Yi et al. (2007) interaction categories are novelty in the literature regarding visualizations of learning trajectories.

- The teachers point of view regarding the presentation and visualization of the learning trajectories and it's possible implications in future works that use or study the visual approach on learning trajectories.

- The improvement of the computational thinking learning process by visual programming via the improvement of teacher visual analysis of the students' learning trajectories.

1.4 Organization

This work is divided as follows:

- Chapter 1 - Introduction regarding this study's domain, it's objectives an contributions.

- Chapter 2 - Fundamentals of this work followed by the studied visualization tools and related works.

- Chapter 3 - Describes the proposed visualizations along with the process of their creation and their literature basis.

- Chapter 4 - Describes the Visualization Evaluation process, detailing the planning of the usability evaluation study, the process of data collection and the execution of the usability evaluation. It also details the analysis process and the threats of validity in this study.

- Chapter 5 - Here are presented the results of the usability evaluation with the results of the analysis presented on the previous chapter. It also presents the participants opinions and discusses several aspects of observed behavior and inferences based on the experiment results.

- Chapter 6 - Presents the conclusions based on the results and analysis of the experiment. States the contributions and possible future work regarding this study.

2 Fundamentals and Related Work

This section presents the concepts of visualization, interaction, computational thinking and visual programming. All of them together constitute the foundation on which this work is based upon.

2.1 Visualization and Interaction

According to Nascimento and Ferreira (2005), one of the main reasons to explore the visualization process is the fact that it involves the human sense that has the biggest capacity of information gathering by unit of time, besides being trained to recognize patterns.

The visualization process can be defined as a cognitive activity, facilitated by external graphical representations in which people construct internal mental representations of the world. A visualization can be considered as an instance of a graphical representation of a certain data set (MAZZA, 2009; NASCIMENTO; FERREIRA, 2005; KEIM, 2002; SILVA, 2014).

The visualizations can further increase the capacity of obtaining information, making it possible for the people to see not only charts, but define which data and how to exhibit it according to their needs. With this objectives in mind the area of Information Visualization or *Infovis* aims to graphically and interactively represent data sets in order to support the acquisition of knowledge. This area intersects computer graphics, optimization and Human Computer Interaction (HCI), using resources that enable data exploration, confirmation of hypothesis and their presentation (NASCIMENTO; FERREIRA, 2005).

Interaction is a vital part of any visualization, as it can greatly multiply the capacity of the visualizations to convey information by adding to it a dynamic aspect not present in mere static images (Yi et al., 2007). Yi et al. (2007) created a classification of actions through which the user can interact in order to better explore the available data proposing seven categories in order to classify the user interaction based on user intent. Such categories encompass most of the possible interactions of the users and are independent of the utilized tool. In the following items we have a brief description of each category.

- Select: Provides to the user the ability to mark a data item of interest and be able to keep track of it.

- Explore: Allows the user to explore different subsets of data.

- Reconfigure: Provides the user with different perspectives of the data set by changing the spacial arrangement of representations.

- Encode: Allows the user to alter the fundamental representations of data, including the visual appearance (for example: color, size and shape) of each data element.

- Abstract\Elaborate: Allows the user to adjust the level of abstraction of the data, giving the ability to go from an overview down to details of individual data cases and often many levels in-between.

- Filter: Enable users to change the set of data items being presented based on some specific conditions. In this type of interaction, users specify a range or condition, so that only data items meeting those criteria are presented.

- Connect: Highlight association and relationships between already represented instances of data, showing hidden data items that may be relevant to a specified item.

With the use of visualizations, professionals in the educational field can better understand the evolution of the students learning by analyzing visually data gathered throughout the learning process (CAI, 2018; RICH et al., 2017; RICH et al., 2018).

2.2 Learning Trajectories

Data collected from students can be used to create learning trajectories or virtual learning paths (RAMOS et al., 2015; RICH et al., 2017; RICH et al., 2018). Learning trajectories are possible paths that the students may follow in order to achieve their learning goals (FORTENBACHER et al., 2013; CAI, 2018; RICH et al., 2017; RICH et al., 2018; MILLER et al., 2014). This trajectories are not static and can be very flexible in such a way that there is not only one way leading to the learning process (TAFNER; TOMELIN; MüLLER, 2012; RAMOS et al., 2015; FORTENBACHER et al., 2013)..

With the help of the learning trajectories and visualizations that can represent them, education professionals may have a clearer view of the progress and trajectory followed by the students, or of possible paths that the students may follow in order to achieve their learning goals (FORTENBACHER et al., 2013; CAI, 2018; RICH et al., 2017; RICH et al., 2018).

2.3 Computational Thinking

Wing (2008) defines computational thinking (CT) as an approach to solving problems, designing systems and understanding human behavior that draws on concepts

fundamental to computing. Raabe et al. (2017) puts the computational thinking as the capacity of systematize, represent, analyze and solve problems. Even though it is a relatively recent term, the computational thinking is increasingly considered one of the cornerstones of the human intellect because it aims to describe, explain and model the universe and it's complex processes. It is often seen as an important competence that is required in order to adapt to the future (RAABE et al., 2017; HSU; CHANG; HUNG, 2018).

Due to the ever growing necessity of an efficient teaching process of computational thinking, several papers have been written approaching this topic. The research field of computational thinking is very vast, ranging from course specifications to the creation of a community and policies of learning and teaching evaluations (MILLER et al., 2014). Despite all the research, teachers and researchers have yet to clearly identify how to teach computational thinking (HSU; CHANG; HUNG, 2018).

2.4   Visual Programming

Programming has been recognized as one of the important competencies that require students to use computational tools to address real-world problems in the 21st century (CHAO, 2016). Visual Programming uses graphic elements in program design distinct from the traditional textual programming languages. In Visual Programming, a program is designed by reusable blocks where the color and shape make it easier for users to identify their functions and whether they can fit together or not (SáEZ-LóPEZ; ROMáN-GONZáLEZ; VáZQUEZ-CANO, 2016).

Related studies have indicated that Visual Programming can increase beginners' efforts into programming learning and help them explore their problem-solving skills when creating projects and solving programming issues (CHAO, 2016). A Visual Programming learning environment can avoid the obstacles posed by complex syntax and help learners to finish projects, which then lead to a better understanding of basic programming concepts among them (TSAI, 2019). We can cite *Code* and *Scratch* among many others as examples of visual programming environments.

2.5   Related Work

This section contains three subsections. The subsection 2.5.1 briefly touches articles that are in some way related to this study. The subsection 2.5.2 summarizes the contributions the different ways that each article contributed to this study. And finally subsection 2.5.3 gives an overview of similar and related visualization tools explored in the literature that provided background, influences and inspiration for the proposed visualizations.

2.5.1   Visualization Work Overview

Silva (2014) and Nascimento and Ferreira (2005) give several notions of the basics of visualizations such as visual concepts, human perception, dimensionality of visualizations, pattern recognition, basic definitions and basic guidelines to make visualizations more effective. Fouh, Akbar and Shaffer (2012) bring to attention the great interest among computer science instructors in using animation and visualization to convey dynamic concepts. They analyze several tools for algorithms visualization and state that the research involved in such tools shows that they generate improvements on the learning process. They emphasize the fact that there is still a lot of room for research in complex interactions between visualizations software, students, learning environments, ways of engagement and learning objectives.

Fields et al. (2016) conducted a study about the assessment of the learning process of young beginners on a learning environment based on projects without a defined ending (projects where the student do not have a fixed goal and must progress as much as possible). Making use of programming analysis in the social context of child learning the author aimed to gather a better understanding of the programming trajectories. The study was conducted with 64 children with ages ranging from 10 to 13 years old and employed the *Scratch 2.0*[1] tool in order to find patterns in the blocks of code used by the participants, allowing the study of the utilized concepts. In the paper the authors emphasize the importance of the qualitative and quantitative tests for the analysis of the gathered data and brings to attention the limiting factors of the study. Despite of dealing with programming trajectories, which can be considered to be a kind of learning trajectory, the paper neither explores different ways of representing the same trajectory nor evaluate any usability aspect of such representations.

The work of Hsu, Chang and Hung (2018), a meta-review of studies published in academic journals from 2006 to 2017 was conducted analyzing application courses, learning strategies, tool of teaching, participants, programming languages and categories of courses of computational thinking education. They found that the promotion of computational thinking progressed greatly in the last decade, coming to the conclusion that most of the research is centered on Problem-oriented Learning, Project-oriented Learning, Game-based Learning and Cooperative Learning. They also give five suggestions in order to improve research on computational thinking: *Educate faculty about CT*, *Effectively assess students' learning performance*, *Know about students' learning status*, *design CT training courses for different ages using appropriate strategies* and *Adopt the cross-domain teaching mode.*

Popat and Starkey (2019) analyze educational outcomes for children learning to code at schools by doing a systematic review with the objective of identifying relevant articles and thematic analysis to synthesize the findings. With the inclusion of ten articles

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[1]   <https://scratch.mit.edu/download/scratch2>

in the synthesis, the authors demonstrate that when students are learning to code, besides being exposed to computational thinking, they can learn or practice a number of other educational outcomes such as mathematical problem-solving, social skills, critical thinking, self management and academic skills while also stressing the importance of instructional design for developing these educational outcomes through coding.

For the purpose of assessing the use of a Visual Programming Language using *Scratch*[2] in classroom practice Sáez-López, Román-González and Vázquez-Cano (2016) analyze the outcomes and attitudes of 107 primary school students from 5th to 6th grade in five different schools in Spain. In their study, students interact and create their own content related to curricular areas with several advantages, such as commitment, enthusiasm, fun, and motivation, showing improvements related to computational practices and computational thinking. The students got a better understanding of computational concepts through an active approach, Project Based Learning, usefulness, motivation, and commitment. The authors conclude the study stating the importance and effectiveness of implementing a Visual Programming Language from active methodologies in primary education.

Making use of questionnaires and visual programming activities, Rose, Habgood and Jay (2017) conducted a study of 158 students in a course of science of information and communication. By the means of visual programming activities involving a robot and cards that dictate it's programming, the authors conclude that the visual programming can be very important to the development of multiple perspectives of computational thinking. The article however does not addresses the learning trajectories of the students nor does it approaches the visualizations of such results in the light of learning trajectories.

Aiming to investigate the effect of teaching *Code.org*[3] site on reflective thinking skills towards problem solving Kalelioğlu (2015) works with 32 primary school students. The authors tackle issues like history of teaching programming to children and gender differences before describing a five week experiment with activities on *Code.org*, ultimately finding that the students developed a positive attitude towards programming in spite of not further developing their reflective thinking skills.

Hammer and Sikorski (2015) discuss the learning progressions by defying the notion that they are only generalizable sequences. The paper stresses the coherence and aggregation of data, stating that the coherence is not static and that possible outliers on the data may contain valuable information that should not be discarded only because they do not fit in any pattern.

Tafner, Tomelin and Müller (2012) deal with learning trajectories and their importance in the teaching process and in the knowledge construction process. Making use of the

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[2] <https://scratch.mit.edu>
[3] <https://code.org/>

Virtual Learning Environments - VLE (learning environments that favors the construction of knowledge (COSTA, 2004)), they discuss the fact that trajectories are virtual learning paths capable of promoting and developing competences regarding to knowledge, skill, attitude, interaction, interactivity and autonomy. According to Tafner, Tomelin and Müller (2012), the conception of leaning trajectories favors the optimization of performance and utilization of the VLEs. The author focus in a general evaluation of the performance of the new VLE presented but limits itself to only that. No analysis are made regarding comparisons of different ways of representing learning trajectories in a visual manner.

Regarding learning trajectories Yang et al. (2015) using the *Scratch* tool measures three main aspects of learning of 3852 users: amount learned, speed of learning and previous knowledge potential. The increase in the users vocabulary is also measured. Using the learning trajectories of the users, they are divided into four groups with canonical patterns through a clustering method. The paper focus mainly on the analysis of student's performance, never mentioning anything about adherence in the representation of data to the teachers in the way of learning trajectories.

On the visual exploration of data, Keim (2002) states that the visual exploration and visual data mining has a great importance on exploration of big sets of data, specially when automated methods fail. The author approaches several different ways of visualizing and analyzing data visually. Explores data dimensionality with ways to deal with multidimensional data, the use of text and hypertext, hierarchical aspects of graphs, software and algorithms. He also approaches visualization, interaction and distortion techniques, concluding that the visualization can help solve the problem of exploring large data sets and stresses the potential of visual exploration in applications such as fraud detection and data mining.

In a systematic literature review Ramos et al. (2015) investigate how the learning trajectories are represented on the e-learning systems and if the representations were viewed only by the students or by students and teachers. They conclude that most of the learning trajectories are represented by graphs (in the case when the student can trail several trajectories during the learning process) following by sequencing (in the case of linear learning trajectories which delimit one single way to be trailed).

Kuosa et al. (2016) explore tools that make use of data gathered from users in order to generate interactive visualizations. Such visualizations allows the students and teachers to analyze their progress on the classes, encouraging a higher engagement. In spite of not discussing learning trajectories per se, the authors approach the use of recorded information as a way to enhance the engagement of students and assist teachers understand the level of learning achieved by their students.

Rich et al. (2017) present an analysis of 108 papers from which they extracted 600 learning goals. Learning goals in this case refers to any explicit statement or implicit

endorsement of what students can or should be able to do in relation to computational thinking. They categorized and clustered the learning goals and later assembled them into learning trajectories. The authors connect the learning goals using relationships and dependencies that define potential pathways through the goals based on the available literature, creating three types of computational learning trajectories: sequence, repetition and conditionals.

In the same field of the aforementioned article, Rich et al. (2018) presents a learning trajectory used for decomposition in a context of computational thinking and computer science. Using 63 leaning goals representative of decomposition extracted from the literature and later synthesized into 13 consensus goals, the authors makes predictions using conceptual frameworks about which trajectories can be followed by the students regarding such consensus goals. In Rich et al. (2018) opinion, the learning trajectory consists in a prediction about a possible learning path. The author however does not present any visual evaluation about the effectiveness of the representations of such trajectories, only presenting a theoretical analysis using the available literature.

Borba et al. (2016) summarize the learning trajectories scenery through a systematic literature review. The paper analyses 25 different articles in the english language and tackles the following research questions: *Is the learning trajectory of the students the objective of investigation in VLEs?*, *How do VLEs capture such information?*, *What kind of analysis are made?*, *What tecniques are used?*, *What are the visualizations of the discovered trajectories?*, *What are the consequences for the process of learning-teaching.* The authors found out that the most common analysis made are the most frequent path (57%), followed by comparisons between trajectories (14%), patterns of behavior (14%), traveled path (11%) and trajectories of cognitive process (4%). The authors noted that only one paper had generated the visualization of the learning trajectory, and did it so in a automated way concluding that, in general, no visualizations of the learning trajectories are generated. Some of the papers used visualizations only to exemplify or demonstrate some concept to the reader.

Carmo, Gasparini and Oliveira (2019) gathered student data in order to use their trajectories to analyze their navigational patterns. Their learning trajectories were captured and visually represented. The study showed that students often prefer a navigation based on concepts and in a linear fashion. The study is however incapable of linking the educational resources accessed by the students with their performance. The paper presents a visualization based on Ramos et al. (RAMOS et al., 2015) conclusion regarding the way of representing the trajectories and is presented as a convoluted graph representing the student navigation trajectories.

We can concluded that in spite of the fact that some articles do approach the learning trajectories and the way the are visually represented (RAMOS et al., 2015;

CARMO; GASPARINI; OLIVEIRA, 2019), there is a gap regarding the way the learning trajectories are presented to the teachers and in which ways the graphical representations of learning trajectories would be more adherent to the teachers needs.

2.5.2   Related Articles Comparison and Contributions

This section summarizes in the Table 1 the related articles mentioned on the previous section, comparing it's topics side by side while stating what was their main contribution to this work. The first column contains the name and author of the articles. The second column shows what topics are approached by the articles and the third column states the contribution that each article had in this work. Some of them contributed more directly providing guidelines, suggestions, insights or good practices that were followed in some aspect of the construction of the visualizations. Others helped by providing the basis of concepts such as computational thinking, visual programming and learning trajectories.

Table 1 – Related articles and their contributions to this work

Title\Author	Article topics	Contribution to this work
Information Visualization and Visual Data Mining (KEIM, 2002)	Visual exploration of data	Provided guidelines on the construction of the visualizations
Visualização de Informações – Uma Abordagem Prática (NASCIMENTO; FERREIRA, 2005)	Basic visual definitions, problems, examples, shapes, colors, graphical properties	Provided examples of design of shapes, colors and positioning of visual elements
The Role of Visualization in Computer Science Education (FOUH; AKBAR; SHAFFER, 2012)	Algorithm visualization	Provided examples of algorithm visualization and visualization of the student's code
Visualização de informação: introdução e influências de IHC (SILVA, 2014)	Human visual perception and information processing, physiological aspects, perceptual processing, visual mapping, visualization effectiveness	Provided important notions of visualization taking the human perception and physiological aspects into consideration
Combining Big Data and Thick Data Analyses for Understanding Youth Learning Trajectories in a Summer Coding Camp (FIELDS et al., 2016)	Learning trajectories, Data analysis	Provided examples of analysis of concepts and code on the visualization
An Exploration of the Role of Visual Programming Tools in the Development of Young Children's Computational Thinking (ROSE; HABGOOD; JAY, 2017)	Visual programming	Provided Visual programming visualizations examples

Continuation of Table 1

Title\Author	Article topics	Contribution to this work
Implications of Complexity for Research on Learning Progressions (HAMMER; SIKORSKI, 2015)	Importance of outliers in learning progressions	Provided comparison between different trajectories and easy visualization of outliers
Trilhas de Aprendizagem:Uma Nova Concepção nos Ambientes Virtuais de Aprendizagem-AVA (TAFNER; TOMELIN; MüLLER, 2012)	Learning trajectories	Provided examples and guidelines for the creation process of the proposed learning trajectories visualizations
Uncovering Trajectories of Informal Learning in Large Online Communities of Creators (YANG et al., 2015)	Visual programming	Provided notions of usability evaluation and student vocabulary variation on each activity
Adaptive Learning Practice for Online Learning and Assessment (CAI, 2018)	Visualization of students learning trajectories	Provided examples of disposition of the learning trajectories, aspects of learning trajectories
Trilhas de Aprendizagem em Ambientes Virtuais de Ensino-aprendizagem: Uma Revisão Sistemática da Literatura (RAMOS et al., 2015)	Learning trajectories and it's visual representation	Contributed with the shape of the learning trajectories presented
Interactive Visualization Tools to Improve Learning and Teaching in Online Learning Environments (KUOSA et al., 2016)	Algorithm visualization	Provided examples of algorithm representations
K-8 Learning Trajectories Derived from Research Literature: Sequence, Repetition, Conditionals (RICH et al., 2017)	Learning goals, learning trajectories	Provided insight on what concepts to show on the learning trajectories
Decomposition: A K-8 Computational Thinking Learning Trajectory (RICH et al., 2018)	Learning goals, consensus goals of learning trajectories	Provided insight on what concepts to show on the learning trajectories
Captura e visualizaçao da trajetória de aprendizagem do aluno: um mapeamento sistemático (BORBA et al., 2016)	Learning trajectories overview and representation	Provided knowledge on ways of presenting learning trajectories to the users
Captura e Visualização das Trajetórias de Aprendizagem como Ferramentas para a Análise do Comportamento dos Estudantes em um Ambiente Adaptativo Educacional (CARMO; GASPARINI; OLIVEIRA, 2019)	Student's data collection, visualization of learning trajectories	Provided basis for the creation of the proposed learning trajectories

Continuation of Table 1

Title\Author	Article topics	Contribution to this work
A new way of teaching programming skills to K-12 students: Code.org (KALELIOğLU, 2015)	Role of visual programming in education	Provided basic notions of importance of visual programming
How to learn and how to teach computational thinking: Suggestions based on a review of the literature (HSU; CHANG; HUNG, 2018)	Meta-review on computational thinking articles	Provides a general outlook of the computational thinking literature
Learning to code or coding to learn? A systematic review (POPAT; STARKEY, 2019)	systematic review of articles related to educational outcomes of programming in schools	Provided a general outlook on the literature regarding programming in schools and it's outcomes
Visual programming languages integrated across the curriculum in elementary school: A two year case study using "Scratch" in five schools (SáEZ-LóPEZ; ROMáN-GONZáLEZ; VáZQUEZ-CANO, 2016)	Use of visual programming language	Provides an assessment of the outcomes of the use of a visual programming language using Scratch in classroom practice

2.5.3   Visualization Tools

This section presents related works that approach visualization tools that help teachers in supervising the students learning process. It briefly describes the tools and the papers in which they were presented. The tools mentioned here were important due to the varied perspectives they presented, providing notions of different ways to present and construct visualizations, aiding in the proposed visualizations creation process.

In their work, Moissa et al. (2014) address the following tools for visualizations: *LeMo*, *WET* e *AdaptWeb*[4]. *LeMo* was developed to capture, among other things, the student's trajectory inside a Virtua Learning Environment - VLE. It is compatible to multiple VLEs like *Moodle*[5], *Clix*[6] and *Chemgapedia*[7]). After making some analysis, the tool generates different visualizations such as the chart of accessed pages, frequent trajectories, time spent on activities, most accessed objects. The *WET* tool can be used with several websites, including VLEs. It possesses as it's main characteristic the capacity to create a visual representation based on the structure, content and utilization of the analyzed

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[4]   <http://adaptweb.sourceforge.net/>
[5]   <https://moodle.org/>
[6]   <https://clix.tiss.edu/>
[7]   <http://www.chemgapedia.de/vsengine/>

website. It's three main visualizations are: the hierarchical representation of the website, the most frequent trajectories traveled from a certain web page and a graph that illustrates all the trajectories traveled. The *AdaptWeb* tool is an adaptive e-learning environment that can show some visual representations of students and their data using bar charts, filters, selection of metrics and tables in detail.

The authors conclude that as the learning trajectories are presented to the teachers, they are capable of improving their understanding regarding the students behavior, even being able to identify or anticipate problems in the learning process. The author discusses different representations of learning trajectories. In spite of the fact that the paper recognizes the importance of such representations, only a preliminary study was conducted to investigate the teacher's preferences regarding the learning trajectories representations. Those preferences are mentioned to be incorporated in the *AdaptWeb* the the future.

Still in the field of VLEs, Fortenbacher et al. (2013) also make use of the *LeMo* tool in order to collect data of students in three different platforms: (*Moodle*, *Clix* and *Chemgapedia*, emphasizing it's interactive visualizations as a differential in comparison to other tools. The authors present visualizations with different levels of detail and several types of charts such as histograms and graphs, analyzing variables such as activity time, performance, and traveled trajectories. They also discuss good practices regarding privacy of the students whose data is being collected and reports the capabilities of the prototype *LeMo* tool to analyze the most frequent learning trajectories. The paper only emphasizes the capabilities of the tool presented, never mentioning anything about different ways of presenting the learning trajectories or it's impact or adherence on the educator's objectives.

Regarding to Adaptative Learning, Cai (2018) presents an evaluation of the *Intelipath* tool which aims to create a learning trajectory based on the knowledge possessed by each student and at the same time help in the assessment and improvement of the classes. The visualizations generated by the tool are available to students and teachers, and represents the learning trajectories by a graph, with each vertex indicating activities and the students mastery over them (using a variation of color and size of the vertices). The paper concludes that there was a measurable improvement in 15 of 16 courses where the tool was used.

Kuosa et al. (2016) explore two tools developed as plug-ins for *Moodle* that use the user's recorded data to generate interactive visualizations, allowing students and teachers to analyze their progress on the courses and promoting a better engagement. The first tool is called *TUT LA tool* and was developed at the Intelligent Information Systems Laboratory (IISLab) at the Tampere University of Technology (TUT). It has three types of visualizations representing the activity and participation levels of each member of student group, a interactive bundle visualization representing relationships between the students, the topics of the learning materials, the web resources referred to,

and the discussions in which the students have participated. It also features an interactive visualization representing the hierarchically structured content of learning material, and uses parallel coordinates and history graphs. The second tool called *TDForum Moodle plugin* was developed at the Unitelma Sapienza University. It extends search functionalities and navigation in the discussion forum of a learning management system with a topic-driven paradigm. It analyses content of forums and automatically identifies topics of discussion and then enhances the original forum with a topic-driven navigation structure and an interactive search graph.

Fouh, Akbar and Shaffer (2012) present several tools for algorithm visualization. Among them they list: *TRAKLA* which let learners "build" a data structure by dragging and dropping Grafical User Interface elements. *JHAVÉ* which interface includes a panel containing the visualization, a panel displaying the pseudocode, and often a brief text giving a tutorial about the algorithm. *ALVIS* which is a program development environment where programs are written using SALSA, a pseudocode-like language. It also includes features to support storyboarding. The *Virginia Tech Hashing Tutorial* provides a complete textbook-quality treatment of an important topic in Computer Science, the concept of search by hashing. *AlViE* - like *JHAVÉ*, *AlViE* is a post-mortem algorithm visualization tool allowing the learner to see the resulting visualization after an algorithm execution. *Alice* is a 3-D interactive programming environment, allowing users to create virtual worlds by dragging and dropping objects in the main windows. *Jeliot*, a tool that is designed to help teach Java programming to high school students. Using the tool, the learner can visualize program source code together with an automatically generated animation that shows the behavior of the program. *ViLLE* is a tool designed to be used as a lecture aid or for independent learning to visualize the execution of example programs created by students or instructors. The user can follow the changes in program states and data structures. *jGRASP* on the other hand provides a complete program development environment with synchronized "object viewers" that let the users visualize objects and data structure states. *JFLAP*, another tool designed to help teach automata theory and formal languages.

2.5.4 Visualization Tools Articles Comparison

Table 2 summarizes papers from the previous section comparing which tools and topics each of them approached. The first column contains the name of the papers and a. The second column contains the tools each paper approaches and in the third column briefly describes in general lines the topics that each paper presented.

Table 2 – Related tools and their contribution in this work

Title\Author	Tools visited	Approached topics
An Information Visualization tool to analyze student's behavior in an e-learning environment and his learning path (MOISSA et al., 2014)	*LeMo*, *WET* e *AdaptWeb*	Visualization examples, Learning Trajectories examples, examples on data visualization using student data
LeMo: a Learning Analytics Application Focussing on User Path Analysis and Interactive Visualization (FORTENBACHER et al., 2013)	*LeMo*	Visualization examples, learning trajectories examples
Interactive Visualization Tools to Improve Learning and Teaching in Online Learning Environments (KUOSA et al., 2016)	*TUT LA tool* and *TD-Forum Moodle plug-in*	Visualization examples regarding participation levels and activities, relationships between students and learning materials
The Role of Visualization in Computer Science Education(FOUH; AKBAR; SHAFFER, 2012)	*TRAKLA*, *JHAVÉ*, *ALVIS*, *SALSA*, *The Virginia Tech Hashing Tutorial*, *AlViE*, *Alice*, *ViLLE*, *jGRASP*, *JFLAP*	Different ways and concepts of algorithm visualization
Adaptive Learning Practice for Online Learning and Assessment (CAI, 2018)	*Intellipath*	Visualization of learning tracks using students knowledge

3 Proposal Elaboration

One of the main premises of this study is to propose learning trajectories visualizations based on the available literature to show data of real students collected in a previous experiment written by Melo et al. (2018) on visual programming. It is also among it's premises to conduct a usability evaluation with teachers from elementary school in order to assess and improve the proposed visualizations based on the gathered feedback while analyzing and searching for correlations between the participants profiles and their understanding of the proposed visualizations. The following sections details the creation process of the proposed visualizations.

3.1 Visualization background

Through the literature review on data visualization I became aware of the concept of visual mining, a process in which combine the flexibility, creativity, and general knowledge of the human with the enormous storage capacity and the computational power of today's computers, integrating the human in the data exploration process (KEIM, 2002). As the research led me to the field of learning trajectories, I discovered that most of the learning trajectories are represented by graphs (RAMOS et al., 2015).

I also became aware that there is no consensus regarding the contents of what the learning trajectories can represent. For Rich et al. (2017) it consists in a prediction about a possible learning path, and is composed of learning objectives and consensus objectives. Tafner, Tomelin and Müller (2012) say they are flexible and alternative paths that lead to the student intellectual development. They are presented as containing hypertext, tips and reminders and are mentioned as part of a Virtual Learning Environment - VLE. Simon (1995) describes them as being a union of learning goals, learning activities and the hypothetical learning process. Steffe (2004) states that they are a model of (children's) initial concepts and operations, a kind of account of the observable changes in those concepts and operations.

My goal was to unite some of these different points of view in a single new visualization (Figure 2) while keeping it, as put by Nascimento and Ferreira (2005), expressive, meaning that it could show all the data the user needed. At the same time it had to be effective, meaning that it would be swift regarding it's understanding aspects and would induce few interpretation errors.

With the purpose of condensing as many characteristics into a single design (Figure 2) I based my proposed visualizations on the works of Yi et al. (2007) which stress

the importance of the interaction for data visualization, stating that with interaction some limits of a representation can be overcome, and the cognition of a user can be further amplified. Yi et al. (2007) proposes seven different categories o visualizations based on their purpose: *Select, Explore, Reconfigure, Code, Abstract-Elaborate, Filter, Connect.* My proposed visualizations make use of all of them except for the *Encode* and have the interaction as a key component. In order to represent several different concepts at the same time without overloading the graphical representation, the interaction aspect is paramount in order to access all the data that would be put in different layers and configurations of the visualization.

I proposed three different visualizations (*Complete Trajectory*, *Single Activity Trajectory* and a modified Bubble chart named "Condensed Trajectory"), composed by graphs and bubbles inside a scatter plot, that would represent each the code submissions of the students or the activities respectively. Each vertex of the graphs and each bubble would consist of a circle filled with a color correspondent to the color attributed to the respective student, surrounded by a donut chart, representing with each slice a concept of its respective activity. The bubbles or vertices would be positioned according to the x and y axis in order to increase the dimensionality of the visualizations, and the interactions would then be used in order to further increase the number of dimensions represented by visualizations. These visualizations are detailed and explained with examples in the following sections.

On Table 3 I briefly relate the papers that were used as base for the creation of the learning trajectories and which aspects of the learning trajectories they contributed to. Other works mentioned in previous sections also contribute, albeit less directly to the creation process of the proposed visualization.

Table 3 – Literature background of the proposed visualization and what aspects of the visualizations were based upon them

Title\Author	Provided basis for
Information Visualization and Visual Data Mining (KEIM, 2002)	Visual exploration and interaction aspects
Trilhas de Aprendizagem em Ambientes Virtuais de Ensino-aprendizagem: Uma Revisão Sistemática da Literatura (RAMOS et al., 2015)	Learning trajectories shape and representational aspects
K-8 Learning Trajectories Derived from Research Literature: Sequence, Repetition, Conditionals (RICH et al., 2017)	Learning trajectories content

Continuation of Table 3

Title\Author	Provided basis for
Trilhas de Aprendizagem:Uma Nova Concepção nos Ambientes Virtuais de Aprendizagem- AVA (TAFNER; TOMELIN; MüLLER, 2012)	Learning trajectories content
Reconstructing Mathematics Pedagogy from a Constructivist Perspective (SIMON, 1995)	Learning trajectories content
On the Construction of Learning Trajectories of Children: The Case of Commensurate Fractions (STEFFE, 2004)	Learning trajectories content
Toward a Deeper Understanding of the Role of Interaction in Information Visualization (Yi et al., 2007)	Interaction categories
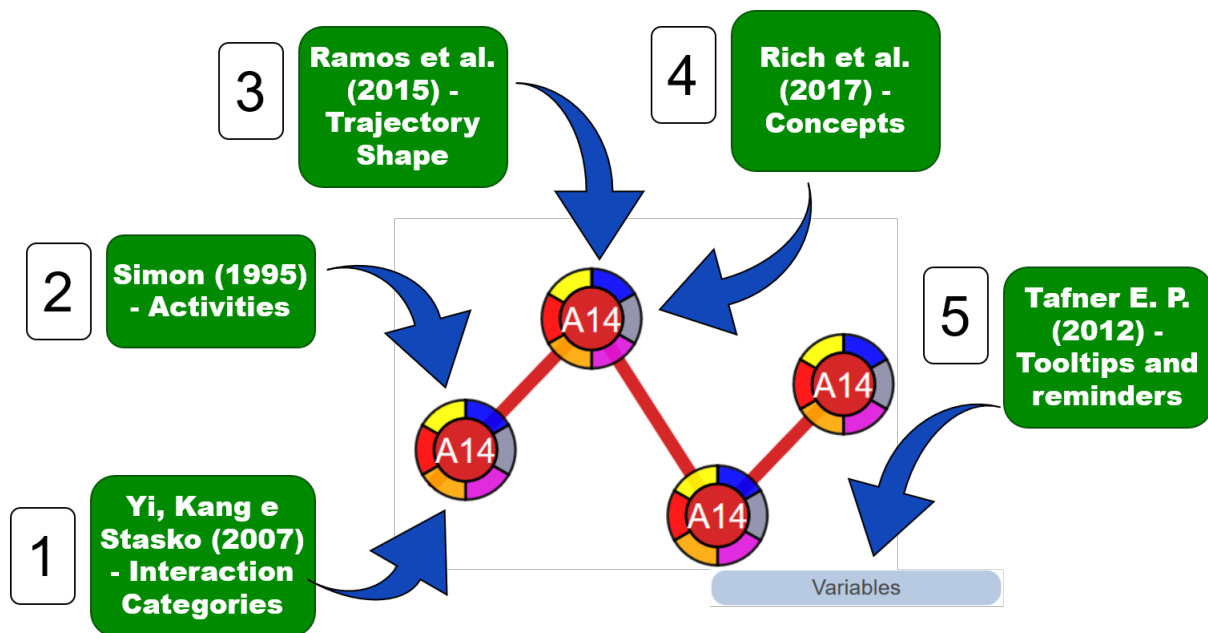
Figure 2 – Concepts inside the learning trajectories and authors they originated from. 1 - Yi et al. (2007) sets the basis for the interaction. 2 - Simon (1995) sets the basis for the representation of activities in the vertices. 3 - Ramos et al. (2015) contributed to the choice of the shape of the learning trajectories. 4 - The initiative to show learning concepts was brought by Rich et al. (2017). 5 - The tool tips and reminders are based on the work of Tafner, Tomelin and Müller (2012)

3.2 Technical aspects

In order to actually construct the visualizations, I researched which set of tools and environments would be the optimum combination of learning speed, accessibility, resourcefulness and customization. I opted to use a Web environment due to it's independence of operating systems, and possibility of being accessed remotely.

I considered the use of three different programming languages to develop the visualizations: *JavaScript*, *R* and *Python*. All the three interpreted languages had libraries and functions capable of crating graphical representations. I chose *JavaScript* together with the *D3*[1] library because of my greater familiarity to JavaScript and for the amount of control that it seemed to give us in the construction of new kinds of visualizations. D3 It also allowed me to easily input and store data into the visual elements. As stated by Kuosa et al. (2016), it is able to provide the flexibility and scalability needed to build different types of interactive visualizations and to use existing solutions to be applied in the context of learning analytics. It also allows for the use of animation, which together with trajectories visualizations can be useful to convey dynamic concepts (FOUH; AKBAR; SHAFFER, 2012).

After choosing the programming language and library, I set up a local server using *Xammp*[2] and imported the data base generated by the Melo et al. (2018)[3] study using *mySql*[4], an open-source database. All the queries were made asynchronously using *PHP*[5]. All the interactions on the visualizations were coded in *Javascript* and all the visualizations created used the *D3* library. The main page was based on *HTML*[6] and all the different visualizations were constructed inside this HTML page.

3.3 Data set of the Learning Trajectories

As a means to compose the learning trajectories I used a data set composed of data gathered from a previous study written by Melo et al. (2018) in the federal university of São Carlos. The data was gathered during an experiment with real students of the elementary school. The experiment involved the students doing a activity in the *Code.org* platform, more precisely the *Star wars*[7] activity. The students would have to use a visual programming tool in order to move a robot through the screen, add commands and different elements to the screen. While they were performing those activities and every time they

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[1] <https://d3js.org/>
[2] <https://www.apachefriends.org/index.html>
[3] <http://www.copictevento.ufscar.br/index.php/ictufscar2018/sorocaba-2018/paper/viewPaper/523>
[4] <https://www.mysql.com/>
[5] <https://www.php.net/>
[6] <https://www.w3schools.com/html/>
[7] <https://studio.code.org/s/starwarsblocks>

would run their code to try and complete the activities, their code would be recorded and stored in a database. This process generated a database containing every piece of code submitted by 48 different students, the time stamp of each submission, and the activity the code belonged to.

The data also had associated with each activity some concepts categorized according to the descriptions provided by *Barefoot*[8], a online platform containing lessons, online guides, computational thinking workshops and programming workshops. The platform claims to empower primary school teachers across the UK to deliver the computing curriculum brilliantly with free face-to-face workshops, helpful online guides and engaging lessons. These concepts were attributed by the previous experiment and were presented in the visualizations in the way they were present in the database, as it was not my objective to remake this attribution, but to show to the users the concepts defined by the original activity from which the data originated. Also in the data there was the code that corresponded to the right answer to each of the activities.

With that data set in hand, I had the gathered data of a experiment with real students that would be used as basis for each of the learning trajectories represented by my proposed visualizations.

3.4   Designing the Visualizations - Conceptions and Construction

This section describes the process of visualization conception and validation which led to the final visualization proposal.

3.4.1   First Version

In order to construct the visualizations of the learning trajectories, I used, beside the literature, the opinion of experts in the form of the *UXLEris*[9] study group. The team is composed of graduate and undergraduate students led by Dr. Luciana Zaina.

At first I made a simple draft of the learning trajectories based on the shape of a graph, which is the most common way of representing the learning trajectories according to Ramos et al. (2015). The graph was drawn together with two axis, being the "y" axis the number of lines of code and the "x" axis the number of tries of the student. I matched the color of the vertices and edges with the color of the name of the student. I also added an eye icon intending to later imbue it with the function of hiding and showing the student's trajectories. Each vertex represented a try or code submission made by the student while solving an activity on the *Code.org* platform. This version could show only the learning trajectory of a single student in a single activity (Figure 3).

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8   <https://barefootcas.org.uk>
9   <http://uxleris.net/>
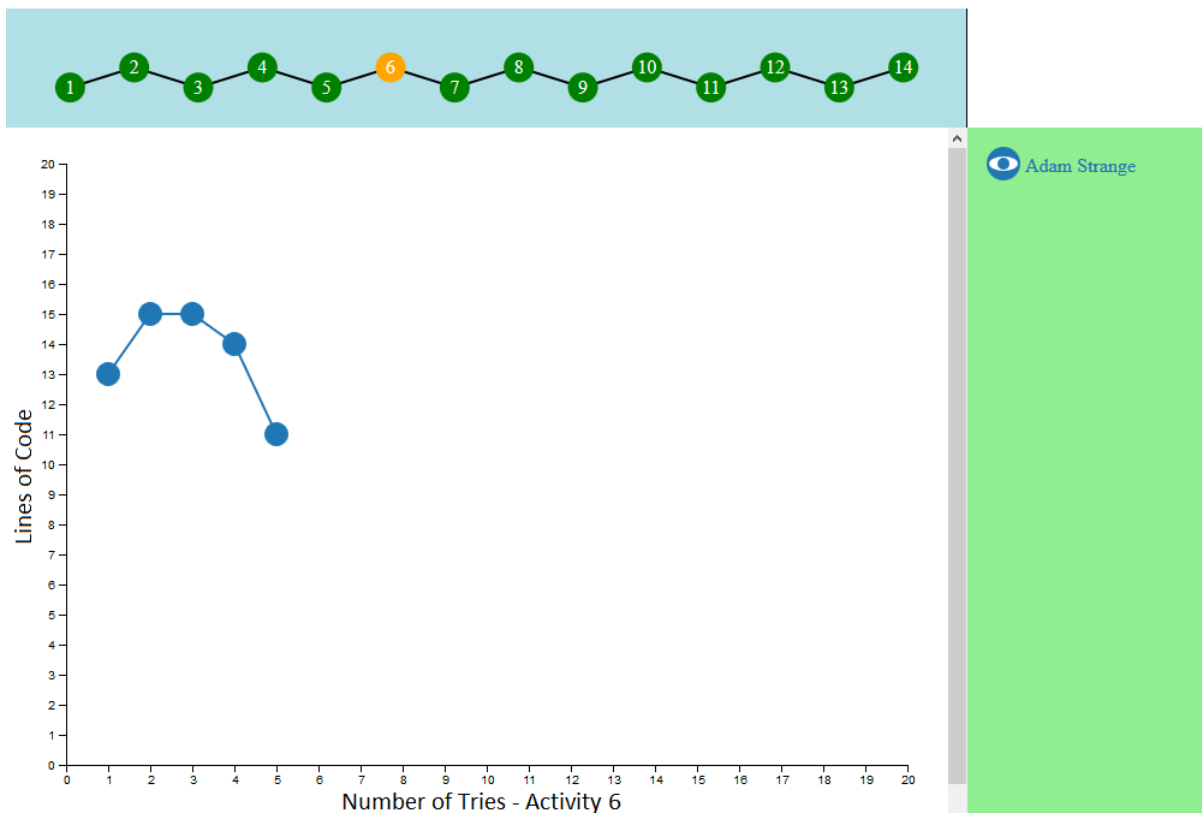
Figure 3 − First Version - Single Activity Learning Trajectory

3.4.2   First Validation

The first version was presented and explained to the UXLeris HCI specialist who suggested adding the number for the activity and also the letter "A" to denote that it meant "Activity" and to make it possible to add multiple students together.

3.4.3   Second Version

I added the letter "A" followed by the number of the activity on each vertex. This second version (Figure 5 and Figure 6) could represent the *Complete Trajectory* of a student through the whole set of activities or a single activity. The eye icon on the panel with the green background now could hide or show the students trajectories. It was possible to show several students at once and the user could add and delete students and hide or show their trajectories. I also wanted to show the concepts of each activity in a similar way as stated in the work of Rich et al. (2017). After some early testing with different geometrical shapes stacked together, each one representing a concept (NASCIMENTO; FERREIRA, 2005), I concluded that it was hard to represent more than 3 different concepts together with this technique (Figure 4) so this idea was discarded. I then decided to add the concepts to the graph in the format of a "sunflower". The vertex of the graph

represented the activity and the petals of the "flower" represented the concepts, or the learning goals, as described by Rich et al. (2017) that the activity would approach. Each "petal" had a different color and different position for each of the concepts as shown in Figure 4. I also added the interaction for the user to see the code of each student by exploring each activity vertex on the graph.
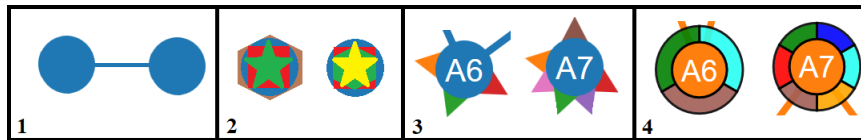
Figure 4 – Evolution of vertices - 1: First version; 2: Second version - experiments with overlapping geometrical forms to represent concepts; 3: Third version - labels and "petals" for concepts; 4: Fourth version - labels and donut chart representing activity's concepts
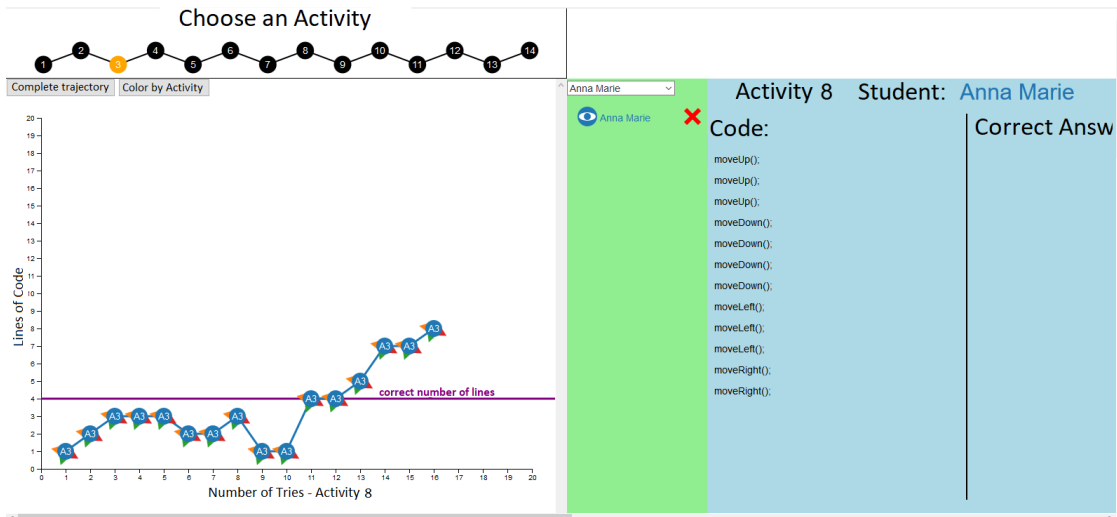
Figure 5 – Second Version - *Single Activity Trajectory* View
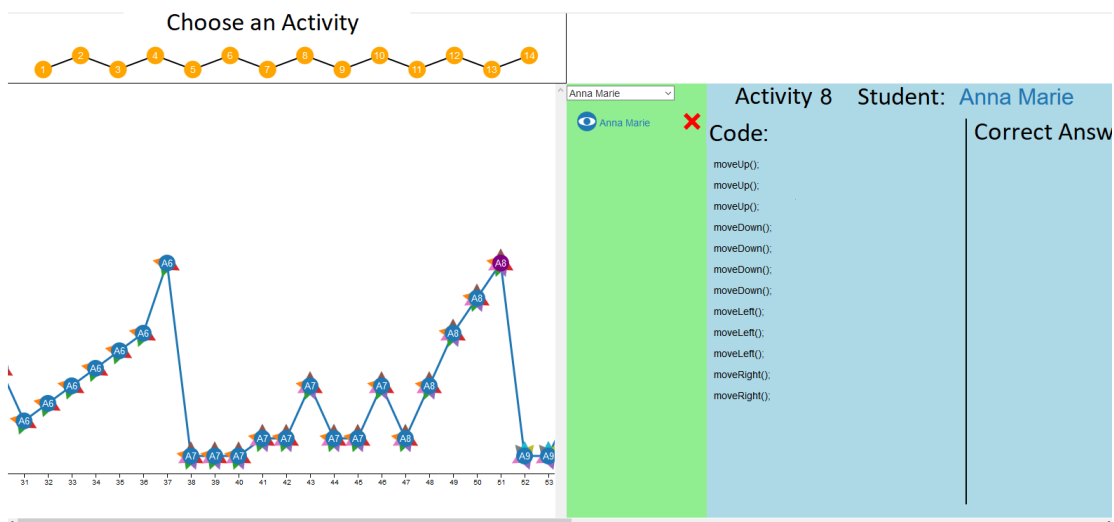
Figure 6 – Second Version - *Complete Trajectory* View

I added the code and tool tips (TAFNER; TOMELIN; MüLLER, 2012) and presented the code of a selected vertex on the right side of the learning trajectories. In this version, the visualization was bigger than the screen and required the user to scroll in order to see the code of the student and the correct code besides it, as seen in Figure 5. The code panel was always visible. I also added a button with the function of coloring the same activities with the same color when the user was using the *Complete Trajectory* visualization.

3.4.4 Second Validation

The visualizations were presented to the UXLeris group in the format of focus group. After presenting the visualization, each member of the group would take turns stating their opinion and suggestions. If the suggestions would reach a consensus between the group it would be accepted and incorporated in the visualization, as long as it would maintain the basic literature concepts initially utilized. I did a presentation of the current features and an explanation on the incorporation of the concepts in the form of petal on each vertex. I also explained the added visual panel that would show the code made by the students. The petals idea was not well received as it made the vertices look unbalanced and the petals were too small and hard to distinguish. This opinion reached a consensus in the group which suggested that the petals would be switched by a donut chart. Each concept would be represented by a slice with a different color enveloping each vertex in order to be easier to distinguish (Figure 4).

The group also suggested the inclusion of a new representation for the *Complete Trajectory* as the participants found it difficult to see the whole trajectory in a single graph which was often times bigger than the visualization chart panel and required scrolling. A bubble chart (Figure 7) was suggested as a way to condense the *Complete Trajectory* graph. The button that colored the same activities on the *Complete Trajectory* visualization was deemed unnecessary and confusing, as the graph lost the color of the students to be colored according to the activities. The group HCI expert also suggested that the code was not shown at all times, but instead appeared only when the user wanted to in the form of a modal.

3.4.5 Final Version

I accepted the group suggestions and made a third version of the visualizations. I swapped the button that colored the vertices according to the number of the activities by a button that showed a modified bubble chart containing the *Complete Trajectory* of the chosen students in a more compact way (Figure 7). The bubbles followed the same aspect of the vertices of the graphs, only loosing the connections between them, giving a idea of a more compartmentalized view on the activities, while the graphs representing
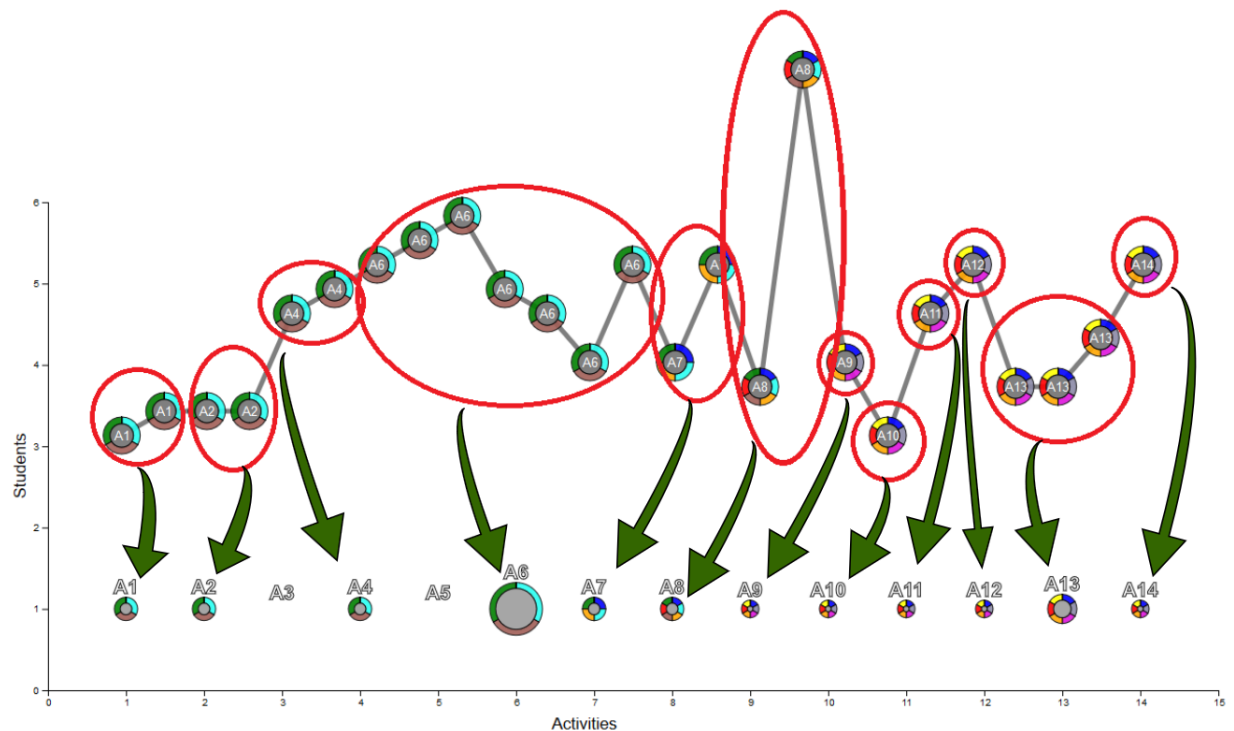
Figure 7 – Condensed Trajectory Construction Concept. The *Complete Trajectory* is compressed into bubbles.

the trajectories gave a feeling of continuity. I also removed the code panel and included the code inside each vertex. The user would have to explore the desired vertex to see the code, which would now appear on a modal panel beside the correct code of the activity in question (Figure 16). I also added a new panel to the top right of the user interface containing the legend for the concepts, and changed what were once "petals" on each vertex into slices of a donut chart. The eye icon was modified to look more like an actual eye and a highlight effect was added together with tool tips on navigation to every element of the visualization that had need for some kind of information or exploration.

The development process resulted on three visualization: *Complete Trajectory*, *Single Activity Trajectory* and *Condensed Trajectory* which are shown and discussed in the next sessions.

3.5 Visualization proposal

I proposed three forms of learning trajectories visualizations: *Complete trajectories*, *Single Activity trajectories*, and *Condensed trajectories*. These visualizations aim to provide teachers with visual information about the path gathered from visual programming platforms (e.g., Code.org). With the purpose of condensing as many characteristics as possible into a single design I based the visualizations on the categories of interaction (i.e., *Select, Explore, Reconfigure, Code, Abstract / Elaborate, Filter, Connect*) presented

in (Yi et al., 2007). These categories stress the importance of the interaction for data visualization rather than exploring only the representational aspect.

The three visualizations were designed from the definition of *visualization spaces*. Figure 22 presents the diagrammatic view of the visualization spaces of my proposal. The *visualization space (1)* presents the area where the *learning trajectories* are displayed. In this space teachers can visually explore the activities visited by the students and their progress as the students worked on the learning of computational thinking concepts. The *Complete trajectories* focuses on showing the whole trajectory of the students while doing the activities. It contains all the available information about the paths of the students in all the activities they did. The *Single Activity Trajectory* is a fragment of the *Complete Trajectory*, focusing on a single activity. And last, the *Condensed Trajectory* provides an overview of the learning trajectories in each activity summarizing the *Complete Trajectory* in a simpler visualization.
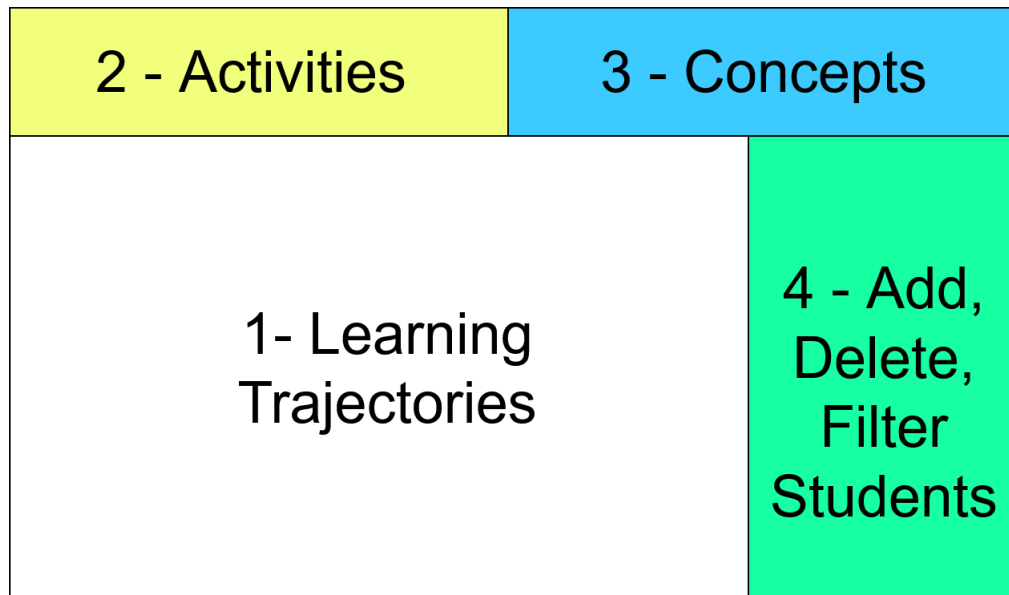
Figure 8 – Diagrammatic view of the *visualization spaces*

As data visualization is tightly coupled to the context from which the data comes, I decided to analyze data types available in Code.org, a well-known platform commonly used to teach computational thinking. Code.org offers an environment where the students can construct solutions using code programming with reusable blocks. It provides lessons based on playful themes (e.g. start wars, barbie) where each lesson is composed by a set of activities with different difficulty levels.

To conduct this analysis, we used a data set gathered during a study[10] with 48 students from two elementary schools in Brazil (MELO et al., 2018). The students performed a set of *Star Wars*[11] themed activities in the *Code.org* platform. This process

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[10]   This study was conducted previously by the research group.
[11]   <https://studio.code.org/s/starwarsblocks>

generated a database containing every piece of code submitted by the participants, the participants name, the time stamp of each submission, and the activity the code belonged to along with the code that corresponded to the right answer to each of the activities. In the previous work, the data had associated with each activity some CT concepts categorized according to the descriptions provided by *Barefoot*[12], an online platform containing lessons, online guides, computational thinking workshops and programming workshops. All the students' names I used in the representations are fictitious keeping the real students anonymous.

Taking into account the interactive aspect of visualizations, my proposal comprises three layers: *representational, navigation* and *exploration.* For each *visualization space* (see Figure 8), I implemented the features of these layers (Figure 9).
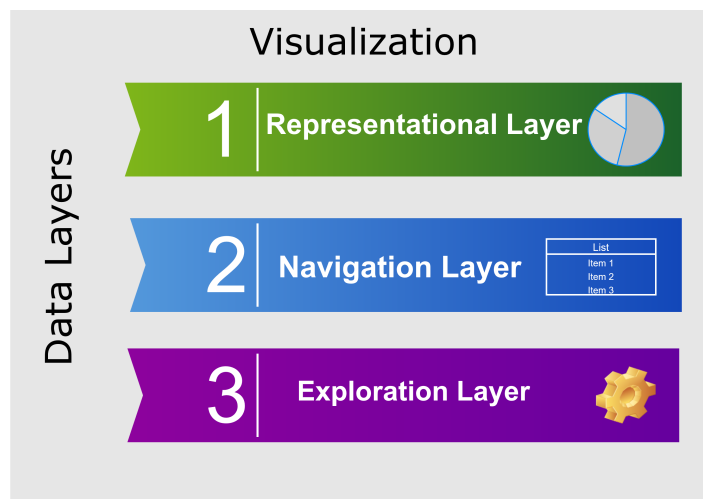
Figure 9 − Visualization Layers

In the *representational layer*, data is displayed through visual elements like charts and icons. The *navigation layers* covers functionalities from which teachers can interact with the visualizations in a more shallow way without exploring data in-depth. For instance, from this layer teachers can see summary of student's data through tool tips when *navigating* the learning trajectories. Finally, the *exploration layer* requires more actions of the teachers to access more detailed data and define which data will be shown (i.e., add, exclude or show data from the visualizations). By interacting with this layer, for example, teachers can access the code written by students along with the right answer to each activity. In a desktop environment with interaction from mouse, the *navigation* and *exploration* layer could be implemented by using resources of "mouse hover" and "mouse click" respectively. In the same way, in a touch interface, these layers could apply the resources of "single tap" and "double tap" respectively. I illustrate in two videos how the *navigation*[13] and *exploration layer*[14] work.

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12   <https://barefootcas.org.uk>
13   Example of the navigation layer: <https://bit.ly/2ZetUFr>
14   Example of the exploration layer: <https://bit.ly/2Vrg29H>

Considering the *visualization spaces* and the data collected from *Code.org*, I built functional prototypes of the three visualizations. In next sub-sections, I present three visualization proposals. For each visualization I give details of their functionalities per layer as well as the interaction categories each one implements.

3.5.1   Complete Trajectory Visualization

Figure 10 illustrates a *Complete Trajectory* visualization. From this visualization, teachers can look at the whole learning trajectory of the students in the course of the activities. This visualization encompass all of the available data, being the most complete of the three visualizations. It also provides a thorough view of the general path each student followed. This visualization allows the teachers to analyze the differences and similarities between the trajectories created by the students learning process.

3.5.1.1   Representational layer.

The *Complete Trajectory* (Figure 10) is represented by a graph inside a scatter plot.
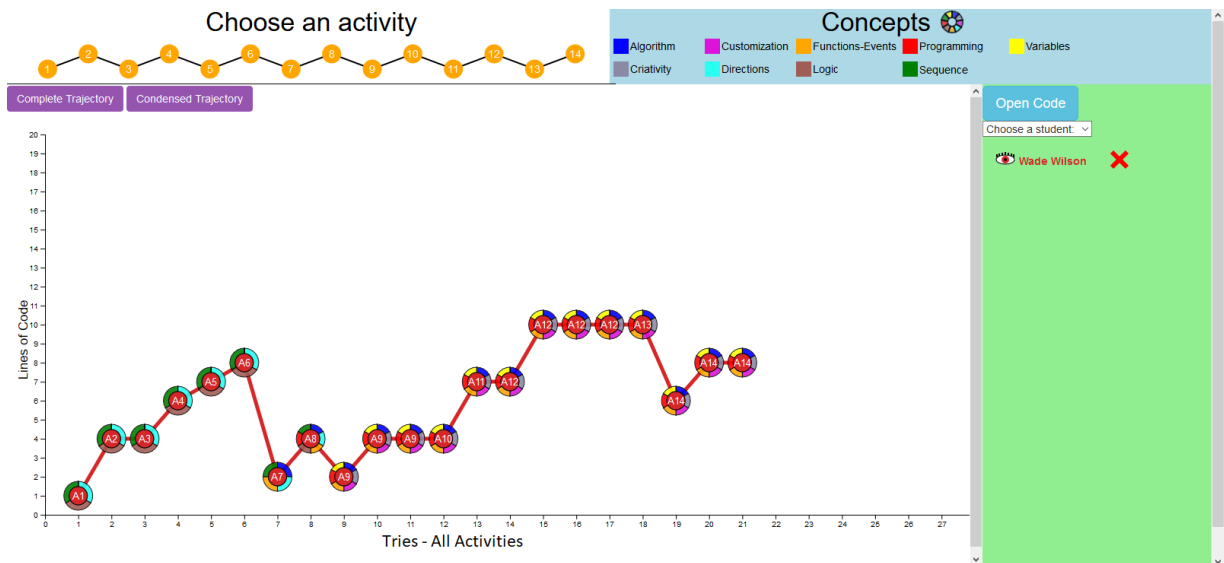
Figure 10 − *Complete Trajectory* visualization of one student.

I chose the graph shape based on the works of Ramos et al. (2015) which concluded that graphs are the most common representation of learning trajectories. Each vertex corresponds to one *attempt* made by the student while trying to solve the activity denoted in each vertex label. I consider as an *attempt* of solving the activity the act of a student piecing together a sequence of lines of code and clicking the "Run" button on the *Code.org* platform. Each vertex of the graph has a label *An* which denotes the *Activity n*. I adopted this labeling way by following Simon (1995) view of learning trajectories. *A1* stands for *Activity 1*, *A2* is *Activity 2* and so on. Each vertex is linked by an edge to give the idea

of connection between the attempts the student did, creating a long linear graph. This graph is also put inside a scatter plot chart, so it uses the axis x and y to convey more information to teachers. The y axis represents how many lines of code the students used while trying to solve an activity while the "x" axis shows the number of times the student attempted to solve an activity. Around each vertex, there is also a donut chart containing all the concepts the activities aimed to teach. The representation of the concepts on the vertices was inspired on the works of Rich et al. (2017) where the vertices also represented concepts. Each slice represents a different concept with a different color.

3.5.1.2   Navigation layer.

The *navigation layer* in the *Complete Trajectory* visualization contains tool tips and data regarding the activities and students.
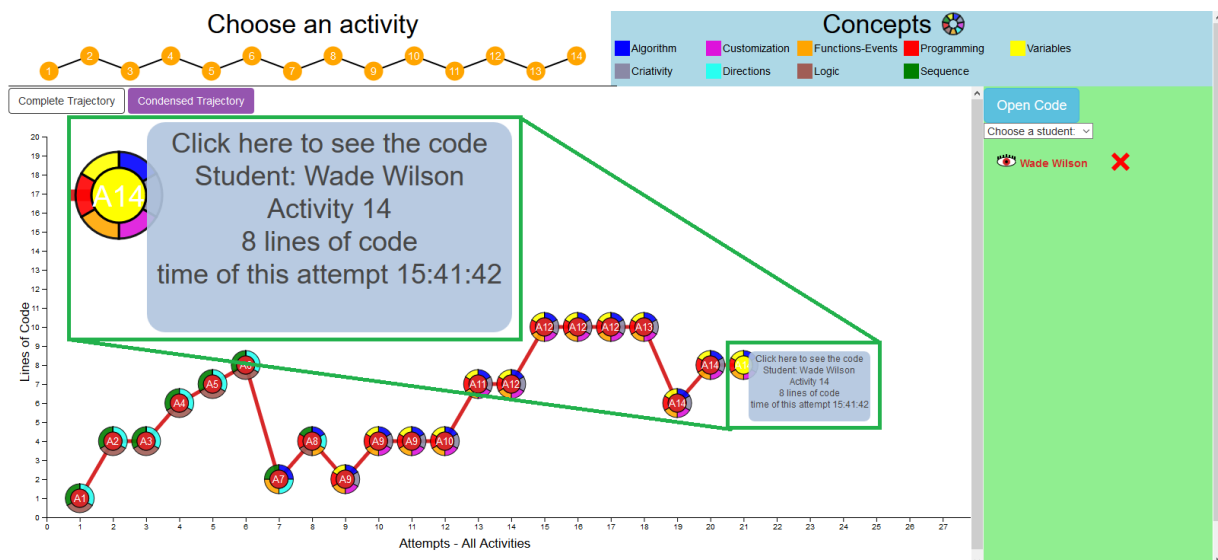
Figure 11 − *Complete Trajectory* visualization of one student with highlighted tooltip from the navigation layer.

This information's details was created based on Tafner, Tomelin and Müller (2012) recommendations. As the user *navigates* the visual elements of the *visualization space (1)*, a tool tip will appear and displays information to the user that is otherwise not shown without any interaction. By *navigating* the vertices, the teacher is presented with the name of the student and the number of the activity that the vertex belongs to, the total number of lines of code written by the student on that attempt and the time of the attempt. If the user *navigates* the donut chart, a tooltip will appear informing the name of the concept *navigated*. Each of the edges connecting the vertices contain the time between attempts, which can be accessed by navigating each edge.

All of the afore mentioned interactions belong to two classes of Yi et al. (2007) interaction taxonomy: *Abstract / Elaborate* when the tooltips shows more information that initially appears on the visualization and *Connect* when it connects all that information on

a single tooltip. This occurs when teachers *navigate* the vertices of the *Complete Trajectory*. *Connect* is also used when teachers *navigate* the edges of the graph, showing the time between two attempts of the student. An example of the tooltip exhibited when a vertex is navigated can be seen at Figure 11. All of the elements from the *navigation* layer can be seen at Figure 12 marked by the green rectangles. One example of each navigation element form all three visualizations can be seen at Table 4 along with the displayed information and the interaction categories they belong to.
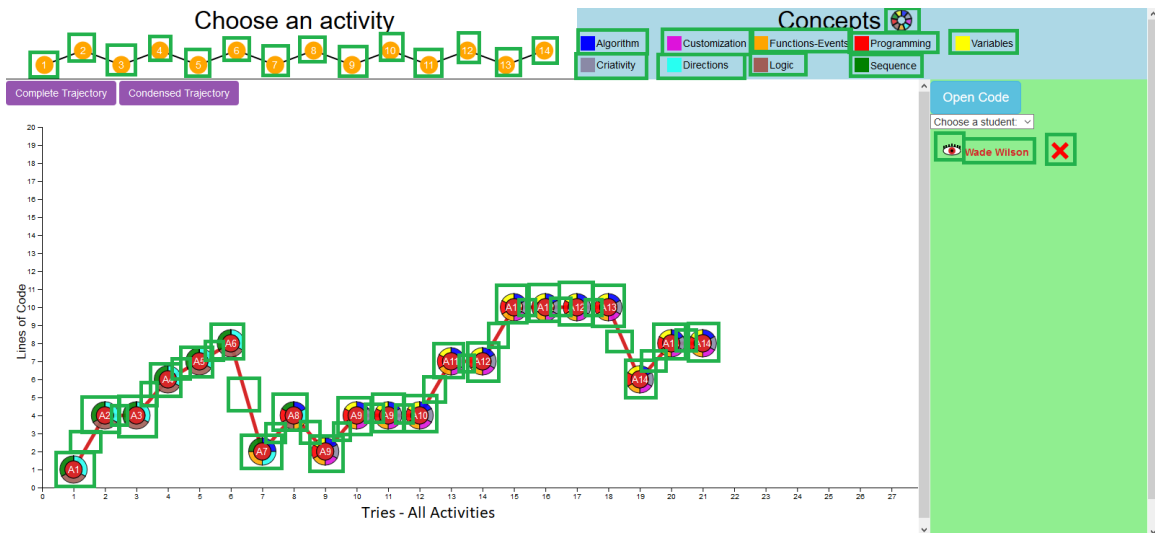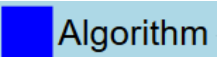
Figure 12 – *Complete Trajectory* visualization of one student with all elements from the *navigation* layer highlighted.

Table 4 – Second Layer - All Navigation Elements - Information Detail and Meta Information

Panel	Interaction element	Interaction action	Displayed information	Interaction categories
1		Navigation	"Click to see the code", Student Name, Activity number, Number of lines of code, Timestamp	Abstract \Elaborate
1		Navigation	Correspondent concept	Abstract \Elaborate
1		Navigation	Student name, Activity number, Number of tries	Abstract \Elaborate

Continuation of Table 4

Panel	Interaction element	Interaction action	Displayed information	Interaction categories
1		Navigation	Time between tries	Connect
2		Navigation	"Click to choose activity"	Abstract \Elaborate
3	Algorithm	Navigation	Highlights elements on panel 1	Connect
3		Navigation	"Click to hide or show concepts"	Abstract \Elaborate
4		Navigation	"Click to Hide or Show in the chart"	Abstract \Elaborate
4	Avi Kaplan	Navigation	"Click to bring to the front on the chart"	Abstract \Elaborate
4		Navigation	"Exclude"	Abstract \Elaborate

3.5.1.3 Exploration layer.

The *exploration layer* is presented in the vertices of the graph considering the recommendations of Yi et al. (2007) and their interactions categories. As the teacher explores them, a modal windows appears (Figure 13), detailing the code written by the student besides the expected code that would correctly answer the activity. The modal also shows the number of the activity and the name of the student. This interaction belongs to the interaction categories of *Abstract / Elaborate*, i.e., showing mode detailed information contained in the visual elements, and *Connect*, i.e., showing the name of the student, number of activity, the code written by the student besides the correct code and connecting all that information together in a single place. Figure 14 shows all the *explorable* elements of the *Complete Trajectory* visualization. Table 5 shows all the *exploration* elements of all proposed the visualizations.
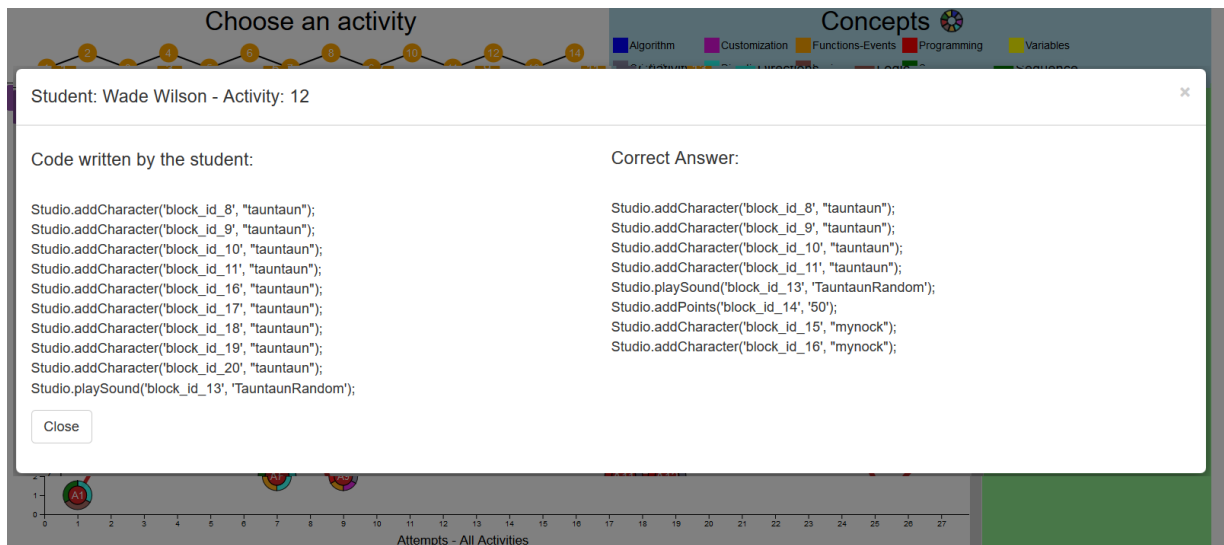
Figure 13 − *Complete Trajectory* visualization - modal window showing the code written
by the student and the correct code besides it

.
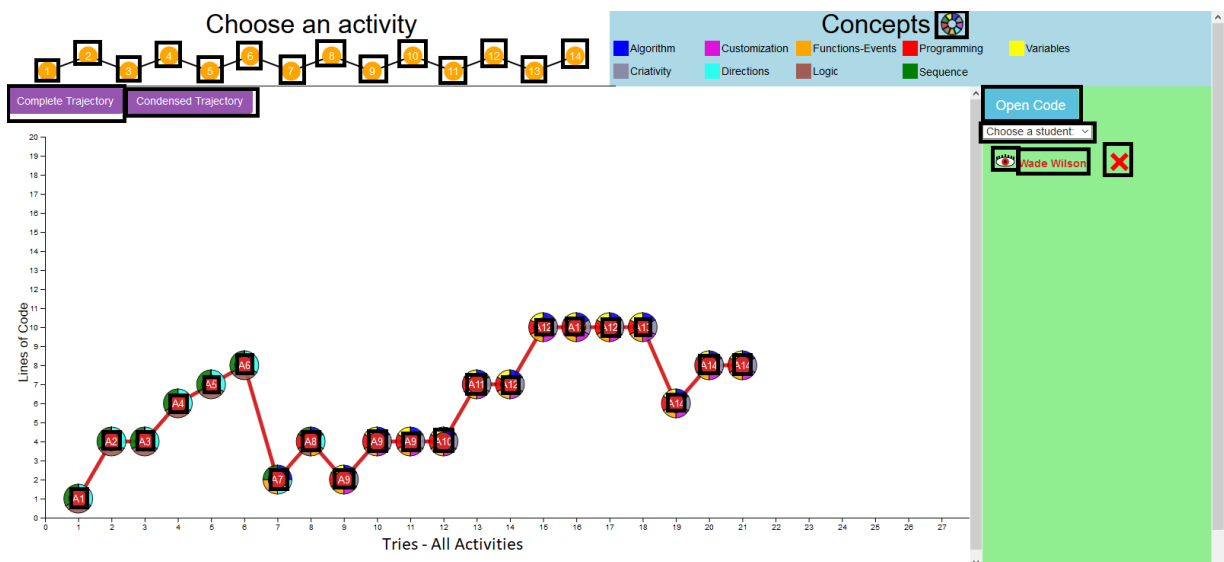
Figure 14 − *Complete Trajectory* visualization - all *exploration* elements are highlighted
with black squares

.

Table 5 – Third Layer - Navigation and data insertion elements of the visualizations

Panel	Interaction element	Interaction action	Displayed information	Interaction categories
1	A2	Exploration	Modal with student's code (**??**)	Abstract \Elaborate
1	Complete Trajectory	Exploration	Shows the *Complete Trajectory* chart	Reconfigure
1	Condensed Trajectory	Exploration	Shows the *Condensed Trajectory*	Reconfigure
2	2	Exploration	Changes activity in panel 1	Abstract \Elaborate, Filter and Explore
3		Exploration	Hide or show concepts in panel 1	Filter
4	Choose a student:	Exploration	Add students in panels 1 and 4	Select, Explore
4		Exploration	Hide or show trajectories of the students in panel 1	Filter
4	**Avi Kaplan**	Exploration	"Click to bring to the front on the chart"	Select
4	✖	Exploration	Exclude student on panels 1 and 4	Filter
4	Open Code	Exploration	Student's code besides correct code, Student name, Activity number	Abstract \Elaborate, Connect

3.5.2   Single Activity Trajectory

The *Single Activity Trajectory* (Figure 16) is a fragment of the *Complete Trajectory*. It is the trajectory of a single activity and allows better analysis between trajectories of different students in a specific activity. It also aligns the attempts of the students of the chosen activity that were most likely misaligned on the *Complete Trajectory* visualization and therefore harder to analyze together. Additionally, this visualization shows the correct number of lines of code as a purple line with a legend on the *visualization space (1)*. The *Single Activity* visualization can be accessed by *exploring* the vertices of the graph on *visualization space (2)*, named in Figure 15 as *Choose an activity*.

3.5.2.1 Representational Layer.

The meaning of visual elements of the *Single Activity Trajectory* is in all aspects identical to the *Complete Trajectory* (Figure 15) except for the fact that it shows only one activity.
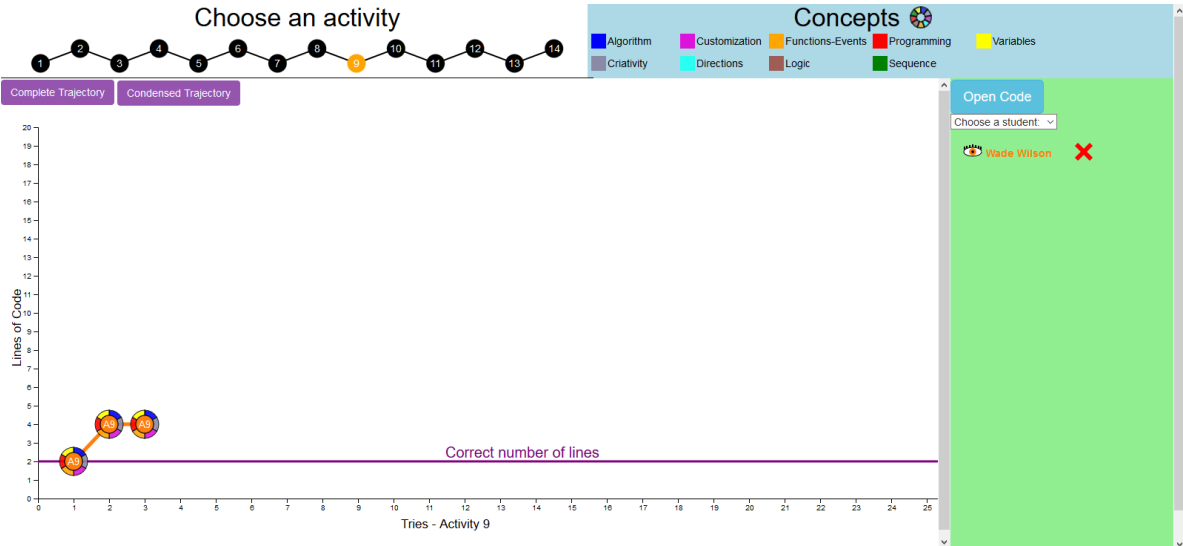
Figure 15 – Representational layer of the *Single Activity Trajectory*.

3.5.2.2 Navigation Layer.

As part of the *Complete Trajectory*, it has the same *navigation* tooltips and information as the *Complete Trajectory*.
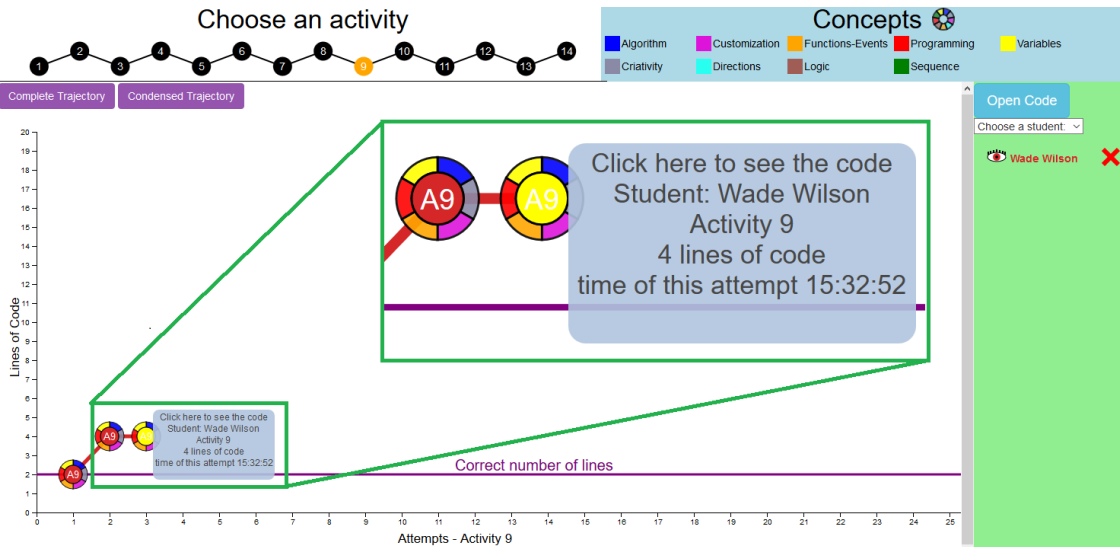
Figure 16 – *Single Activity Trajectory* showing the learning trajectory of activity 9 with tooltip from the navigation layer.

All the navigation of the *Single Activity Trajectory* make use of the same categories of interaction used in the *Complete Trajectory*. An example of the tooltip within the

second layer is shown in Figure 16. All the elements of the *navigation* layer can be seen at
Figure 17 and at Table 4.
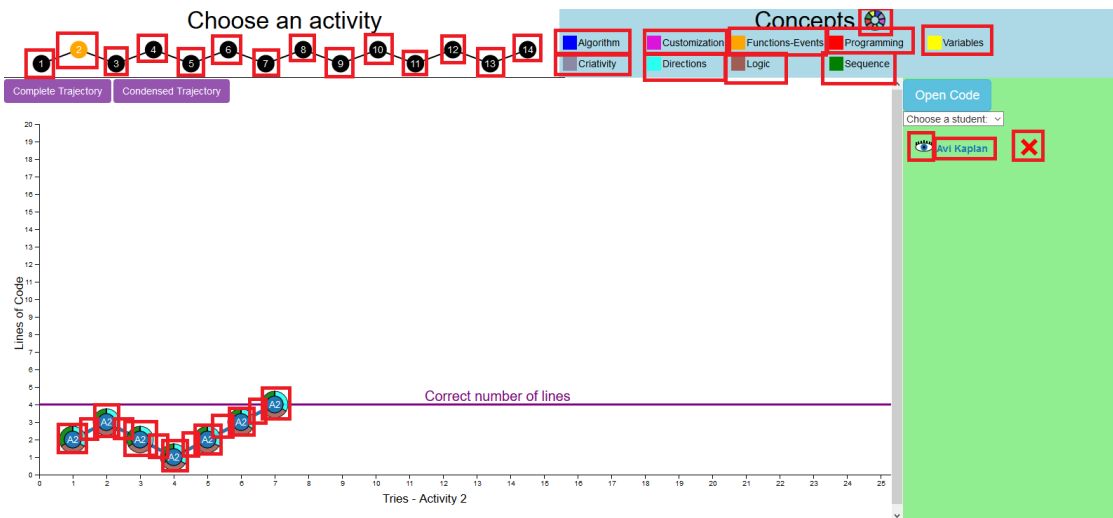
Figure 17 − *Single Activity Trajectory* showing the learning trajectory of activity 2 and
all the elements of *navigation* layer highlighted by red rectangles.

3.5.2.3   Exploration layer.

As part of the *Complete Trajectory*, it has a the same *exploration* aspects and
information as the *Complete Trajectory*. All the *exploration* elements of the *Single Activity
Trajectory* can be seen at Figure 18 and are further detailed at Table 5.
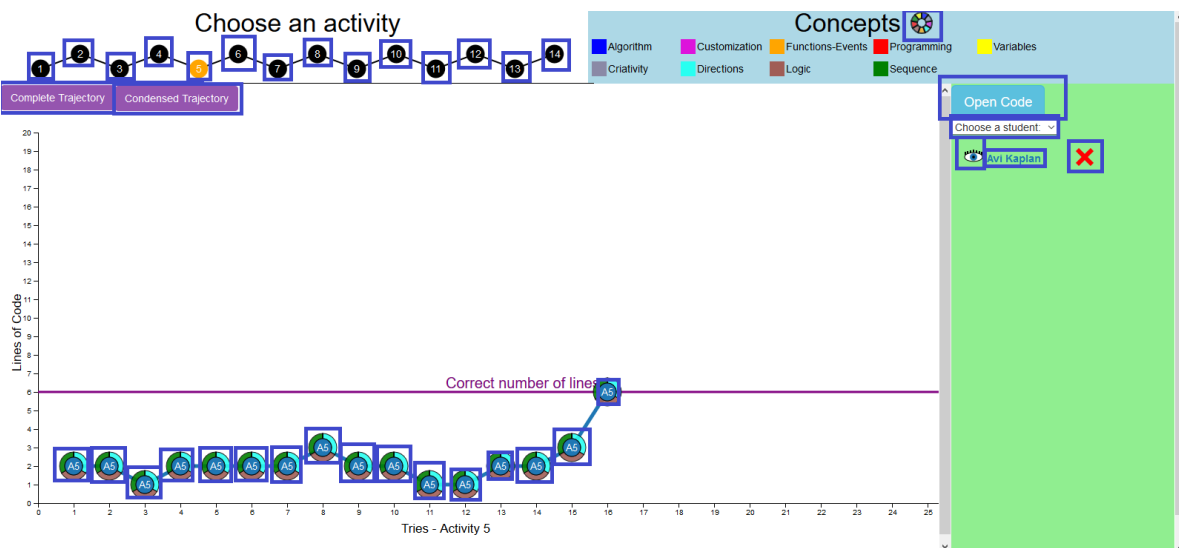
Figure 18 − *Single Activity Trajectory* showing the learning trajectory of activity 2 and
all the elements of *exploration* layer highlighted by blue rectangles.

3.5.3 Condensed Trajectory

The *Condensed Trajectory* is basically a modified bubble chart that also shows the learning trajectory of the students, but in a more concise way (see Figure 7). This visualization facilitates the search for outliers or skipped activities, since it shows one *bubble* for each activity. If the student skipped one activity, there will be no *bubble* for that activity, and a greater number of tries in a particular activity is easily perceived due to the bigger size of the *bubble* representing such activity.

3.5.3.1 Representational Layer.

The *Condensed Trajectory* (Figure 19) compresses the *Complete Trajectory* and its vertices into *bubbles*, one for each activity. The more attempts made to answer the activity, the bigger the *bubble* will be. The "x" axis represents the number of the activity and the "y" axis representing the number of students inserted on the chart. The *AN* (*Activity N*) labels inside or above the *bubbles* denotes which *bubble* represents which activity.
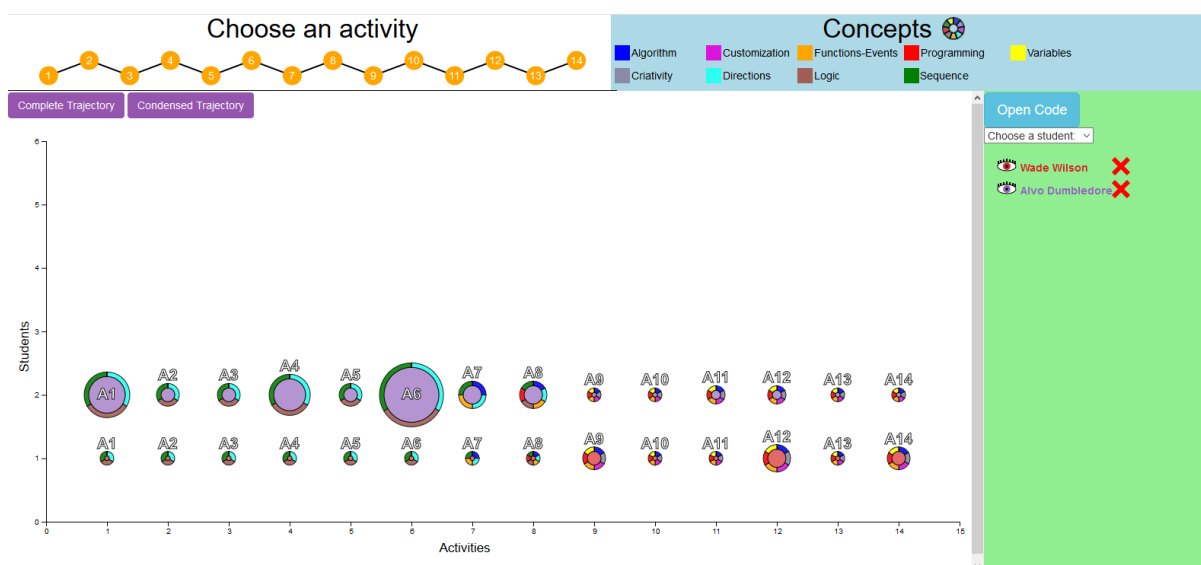
Figure 19 − *Condensed Trajectory.*

3.5.3.2 Navigation Layer.

The *bubbles* once navigated show a tool tip informing the teacher about the name of the student the bubbles belongs to, the number of the activity the *bubble* represents and the number of attempts made by the students. These navigation interactions belong to two classes of the Yi et al. (Yi et al., 2007) interaction taxonomy: *Abstract / Elaborate* for when the tool tips show more information that initially appears on the visualization which is the case when the teacher *navigates* the *bubbles*. *Connect* is used when the teacher *navigates* the *bubbles* and all the information is shown together, connecting it. An example

of *navigation* interaction and the tooltip generated can be seen in Figure 20. All the *navigation* elements can be seen in Figure 21 and are further detailed at Table 4.
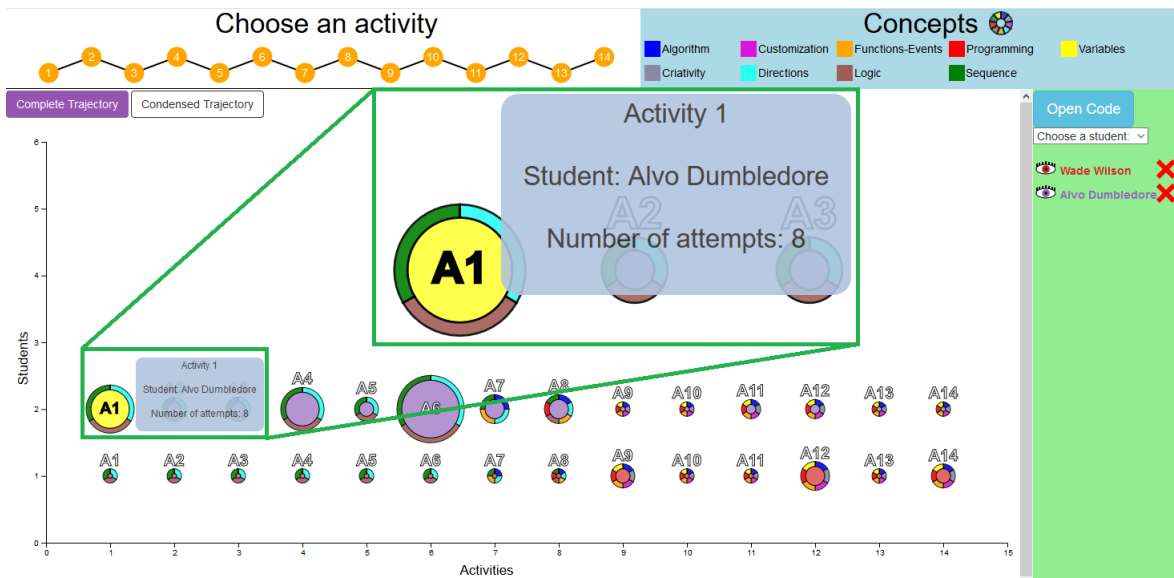
Figure 20 – *Condensed Trajectory* with tool tip from *navigation* layer highlighted.
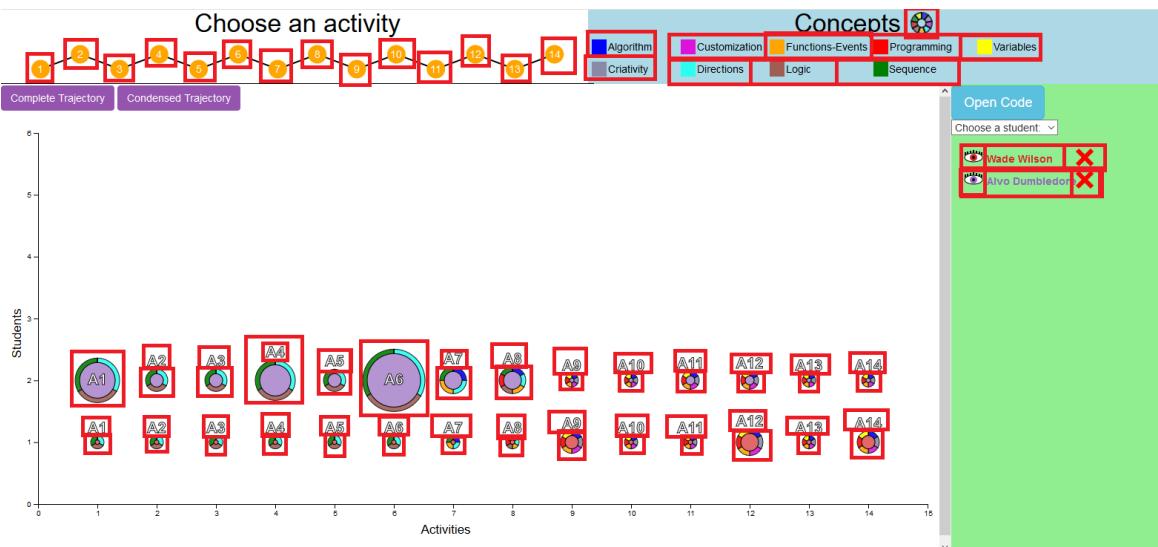
Figure 21 – All the elements of the *navigation* layer of the *Condensed Trajectory*.

3.5.3.3   Exploration layer.

The *Condensed Trajectory* does not possess any interaction in the *exploration* layer. It is intended as a less detailed kind of visualization that summarizes the *Complete Trajectory*, allowing for a quick and general albeit less detailed view of the students' learning trajectories.

3.5.4 Auxiliary Visualization Spaces

The *visualization spaces (2), (3), and (4)* (see Figure 22) serve as auxiliary interaction spaces that allow teachers to control and choose which student, activity and concepts will be shown on the *visualization space (1)*. The *visualization space (2)* contains all the activities and allows the teachers to choose the activities through the *Abstract / Elaborate*, *Filter* and *Explore* categories of interaction. The *visualization space (3)* allows teachers to visually *Connect* concepts with activities and *Filter* concepts. In the case of my proposal, in this space I presented the concepts of computational thinking which are categorized in a previous work. The *visualization space (4)* controls the input of data on the learning trajectories through the interaction categories of *Select*, i.e., the action of bringing a student chart over the other ones, *Explore*, i.e., the action of adding one student, and *Filter*, i.e., hide or show students and delete added students.
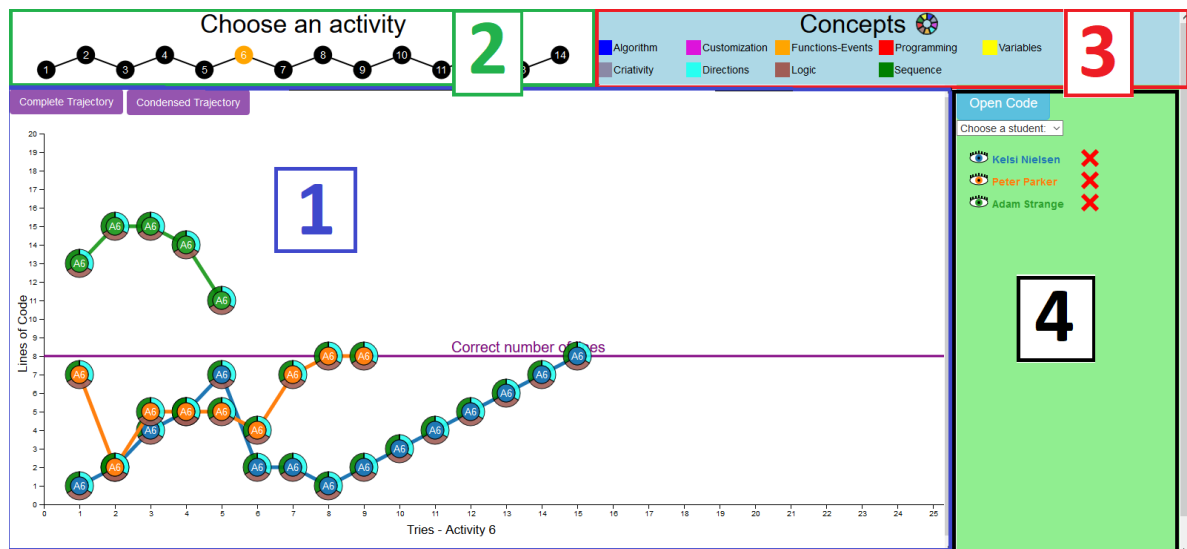
Figure 22 – Visualization Overview - Visualization spaces 1, 2, 3 and 4 and their disposition on the user interface. Here the *Single Activity Trajectory* is depicted showing the activity 6 of 3 students

4 Visualization Evaluation

The evaluation is a key research challenge within the InfoVis community. To develop successful InfoVis techniques it is necessary to assess their disadvantages and merits. The value of evaluation cannot be overestimated (FORSELL, 2010; CARPENDALE, 2008).

This part of the study presents itself as a usability evaluation aiming to assess the proposed visualizations representing learning trajectories gathered in the process of teaching computational thinking in the context of visual programming. The evaluation targeted teachers from elementary education and has the objective of evaluate the proposed visualizations as well as gather data on the teachers understanding and feedback.

The research experiment was conducted at the Federal University of São Carlos - campus Sorocaba and collected information from teachers who were studying at the university and from teachers of two other schools, one public and another private.

Complying with strict ethic and scientific standards, a research project (Ethic Appreciation Presentation Certificate - EAPC 18606019.2.0000.5504 Appendix A) was submitted to the Ethics committee of research in human beings of the Federal University of São Carlos and later approved (Appendix A).

4.1 Planning

The planning of the experiment took into account several aspects, such as the participants needed, the tasks and questionnaires that would be proposed to them, the means of gathering all the generated data and the place and organization of the experiment, duration of the experiment sessions and possible carry over effect (FORSELL, 2010; CARPENDALE, 2008). I created a slide presentation in order to standardize the visualization presentation, and devised three different ways to gather the data from the participants.I also devised a legal term of consent for the use of the participants voices and experiment data that was required by the university's Ethics Committee (Appendix A).

The next sections describe in detail each step of the planning and what was made in order to guarantee that the experiment would occur without any problems.

4.1.1 Introduction of the research

The participants would be notified through several different ways which included posts on social media, emails and later phone calls to different educational institutions. In order to give an welcoming and standard introduction of the contents and objectives of

the research, I created a slideshow (Appendix A) together with a oral presentation and explanation of what the experiment consisted of. In the slides I would briefly introduce and explain the concepts of computational thinking, visualization, visual programming and learning trajectories. I would also explain what data we were using, informing that it was data collected form real students using the Code.org platform and then I would explain the experiment, detailing that each participant would have to answer three questionnaires which are discussed in more detail in the following section.

4.1.2 Data Collection

Data collection was approached in three different fronts: audio, video and questionnaires. I devised three kinds of questionnaires that can be seen at Appendix A and are explained on the following sections. The questionnaires were available at links provided during the experiment and were hosted on google forms. I decided to record the voice of the participants in order to employ the "Think Aloud" (LEWIS, 1993) protocol. This protocol consists of the participants to literally "speak their minds" while performing the activities of the experiment. The participant would speak describing what they were thinking or the actions they are performing. I also planned to record the screen and the participants interactions with the visualization and their actions while they answered the tasks questionnaire. I would use three notebooks equipped with mouses and microphones where the participants could interact with the proposed visualizations and answer the online questionnaires. For the video and audio recording I would use the software stream-LabsOBS[1] a free and open-source software, which is capable of recording the screen of the computer and the audio at the same time.

The profile questionnaire (Appendix A) contained questions used to form a profile about how old were the participants, the knowledge of the participants in charts and their familiarity with the use of the internet, as well as their experience with working as a teacher and with teaching computational thinking, and what kind of apps did they use. The questionnaire questions can be seen in Table 6

Table 6 – Profile Questionnaire

Questions	
Q1 - How old are you?	
Q2 - What is ou education level?	
Q3 - How long have you been a teacher?	
Q4 - How long do you know about computational thinking?	
Q5 - How long have you been teaching computational thinking?	
Q6 - How many times do you access the internet per week	

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[1] <https://streamlabs.com/streamlabs-obs>

Continuation of Table 6

Questions
Q7 - What eletronic devices do you use?
Q8 - What apps do you use with educational purposes?
Q9 - Where these apps are used?
Q10 - What kind of charts do you know?

The tasks questionnaire (Appendix A) contained the proposed tasks that the teachers would have to try to complete. It was planned in such a way that it would suggest the participants to use most of the available features of the visualizations in order to be answered correctly. We also took into consideration some confounding factors. As a means to avoid the Carry Over effect (FORSELL, 2010) an effect that occurs when a participant carries knowledge from one visualization or experiment to the other, the tasks were separated in different categories of the visualizations required to complete, so the completion of a set of tasks would provide little help in the completion of the next set.

In order to verify which concepts of interaction and visualization the participants were working on, each question of the tasks questionnaire was made to make sure the participant would use a target interaction or visualization in order to correctly answer the questions. There were however in most cases more than one way to find the correct answer with the different charts. Table 8 details every task in the tasks questionnaire and what would the participant require to do regarding to the data visualization and interaction part and in which category of interaction (Yi et al., 2007) those actions would fall into. Table 7 shows what categories are present in which tasks in a more concise way.

Table 7 – Tasks and interaction categories (Yi et al., 2007)

Task	Select	Explore	Reconfigure	Encode	Abstract \Elaborate	Filter	Connect
1	X	X			X		
2	X	X	X			X	
3	X	X	X			X	X
4	X	X	X			X	
5	X	X	X			X	
6	X	X	X			X	X
7	X	X	X			X	X
8	X	X	X			X	X
9	X	X	X		X	X	X

Table 8 – Tasks, Visual and Interactions Actions and Visualization Types

Title\Tasks	Visualization Actions	Interaction	Interaction categories	Visualization Type
1 - Looking at the trajectories of the students "Homer Simpson", "Barry Allen" and "Harry Potter", which of them completed the activity 6 correctly?	identify the student's code and the answer's code, use the "correct number of lines" line	select the students, select a specific activity, click on the graph's vertices	Select(insert student), Explore (insert student), Abstract\Elaborate (click the vertices see see the code)	*Single Activity Trajectory*
2 - How many tries did the student "Harry Potter" use in order to complete the task 1?	select the student, identify the number of submissions using the graph's axis on the *Complete Trajectory* or *Single Activity Trajctory* graphs, or locate the correct bubble on the *Condensed Trajectory*	Select the student, select the specified activity	Select (insert student), Explore (insert student), Filter (select an activity), Reconfigure (select an activity)	*Single Activity Trajectory*
3 - Question - Check all the concepts present in activity 9.	identify the concepts in the right vertex or bubbles	select a student, select a specific activity	Select (insert student), Explore (insert student), Filter (select a activity), Reconfigure (select a activity), Connect (concepts, student and activity)	*Single Activity Trajectory*
4 - Question - Considering the students "Barbara Kean", "Bucky Barnes" and "Harry Potter", which of them tried to answer all the activities?	identify activities on the *Complete Trajectory*, or check every activity separately or use the *Condensed Trajectory* and find missing bubbles	select the students, use any of the three charts	Select (insert student), Explore (insert student), Filter (select a activity), Reconfigure (select a activity)	*Complete Trajectory*
5 - Question - How many tries did the student "Mickey Mouse" do in order to complete all activities?	interpret the "tries" axis in the *Complete Trajectory* or *Single Activity Trajectory* graphs, or use *Condensed Trajectory* tool tips	select student, use the charts	Select (insert student), Explore (insert student), Filter (select a activity), Reconfigure (select a activity)	*Complete Trajectory*
6 - Question - What was the time between the last try on activity 6 and the first try on the activity 6 of the student "Mickey Mouse"?	check the time on the edge of the *Complete Trajectory* graph or check the last and first tries of activities 5 and 6 separately	select students, use the tooltips with mouse hover	Select (insert student), Explore (insert student), Filter (select a activity), Reconfigure (select a activity), Connect (time passed between activities)	*Complete Trajectory*
7 - Question - In which activity did the student "Adam Strange" make the most tries?	identify which activity had the most tries.	select the student, use any of the charts	Select (insert student),Explore (insert student), Filter (select all activities), Reconfigure (select all activities), Connect (number of tries with activities)	*Condensed Trajectory*
8 - Question - Which of the three students had less tries on the activity 10?	identify activity 10, identify which of the three students had less tries on activity 10	select the students, use sight and interaction any of the three charts to locate the activity 10 and compare the number of tries.	Select (insert student),Explore (insert student), Filter (select all activities), Reconfigure (select one or all activities), Connect (students with activities and number of tries)	*Condensed Trajectory*
9 - Question - What are the concepts used on the activity on which the student "Peter Parker" made the most tries?	identify the student "Peter Parker" and which activity he tried the least and then identify the concepts of that activity	select student, use the different charts and mouse interactions to identify the student, the activities, number of tries and concepts	Select (insert student), Explore (insert student), Filter(select all activities), Reconfigure(select all activities), Abstract\Elaborate (use *Condensed Trajectory* or specific activity graph), Connect (student with activity with number of tries and concepts)	*Condensed Trajectory*

The Self-Assessment Manikin (SAM) (BRADLEY; LANG, 1994) questionnaire (Appendix A) served the purpose of measuring three aspects of the user emotional experience about the visualizations: arousal, pleasure and dominance. Each participant should mark in each category the level (from 1 to 9) of these three aspects that they had experienced during the experiment. Together with the SAM questionnaire I used two open questions asking what the participant would change in the presented visualizations and what was their opinion and suggestions on the visualizations used during the experiment.

4.2   Execution

With a total of 23 participants, each session of the experiment was programmed to last one hour at most so as to not tire the participants. I used ten minutes to present the slides and give a quick explanation about the experiment, the visualizations, visual programming and computational thinking. No sessions used more than the stipulated time.

The evaluations occurred in the course of several days with teachers from three different educational institutions. Every time we would have a laboratory and two or three notebooks in order to conduct the experiment. Every notebook had the visualizations and links of the questionnaires prepared. I also used a projector or a notebook when a projector wasn't available each time new participants arrived so we could explain the experiment using the slides, in case that hadn't been already done to the group of participants.

I divided the participants in groups of two so they could sit in opposite sides of the rooms and not disturb each other with the "Think Aloud" protocol. Also with two participants we could give proper attention to the participants whenever they had any doubts about the activities they were supposed to complete.

After the slides presentation, we informed that the participants would have to read, agree and sign authorization forms (Appendix A) of the research if they wanted to participate. After that I would explain that each participant should answer the profile questionnaire, and as soon as that was done they could start the experiment. The recording software would then be turned on and the visualizations would be made available together with the tasks questionnaire. The participants then would have to read the tasks presented in the tasks questionnaire and look and interact with the visualizations provided so they could try to answer the proposed tasks.

After the completion of the tasks, I would ask that the participants answered a final questionnaire about their experience with the visualizations. Such questionnaire included a SAM questionnaire and two open questions where each participant could inform us about changes that they would do to the visualizations if any and suggest something regarding the visualizations if they wished to do so.

4.3 Analysis

In order to analyze the experiment's results I had three main data sets: The answers to the questionnaires, the voice of the participants and the video containing their interaction with the visualizations.

Alone, each of those three sets of data would not capable of providing a clear picture of the user experience during the experiment. Together however, the three data sets formed a rich landscape of the participants impressions, doubts and learning process. I opted to use *triangulaton*, the application and combination of several research methodologies in the study of the same phenomenon (DENZIN, 2015).

By using the Think Aloud Protocol (LEWIS, 1993) I was able to extract from the voice recordings all the words and phrases the participants had said and later apply the Open Coding, an analytic process through which concepts are identified and their properties and dimensions are discovered in data (KHANDKAR, 2009). First the data is coded, which means that parts of the text are given a code representing a certain theme, area, construct, and so on. One code can be assigned to many pieces of text, and one piece of text can be assigned more than one code. This way the codes can form a kind of hierarchy of codes and subcodes. Then the coded material can be combined with reflections or comments made by the researcher. When this process is done, the researcher can go through the resulted material and identify the first set of hypothesis (RUNESON et al., 2012).

I used this process to open up the text and expose the thoughts, ideas, barriers, obstacles and meanings contained therein (STRAUSS; CORBIN, 1998). In order to do so, I wrote down all that was said during the experiment. Then, for each participant I classified the phrases in three categories: Green symbolizing understanding, orange symbolizing obstacles and doubts(problems that the user could get across) and red symbolizing barriers (which made impossible for the user to understand or accomplish a task), yellow my comments and considerations and white being words or phrases that had nothing to do with the experiment and could be excluded from the analysis. I classified the codes in two major classes, the first one being "positive assertions" containing the green codes, and the second one, "negative assertions" containing the red and orange sub classes (Appendix A).

The total time of the video recordings amount to almost 7 hours. After a initial analysis of all the video recordings, I decided to exclude 3 participants on the account that they did not use the visualizations in order to answer the tasks questionnaire. So from the initial 23 participants only 20 were used in this study.

Together with the Open Coding, I also applied the study of the videos paired with the tasks questionnaire. By analyzing both of them I had the answers of each participant, and could watch the trajectory that led to each answer. As I saw the participants progress

through the activities, I could clearly verify how the answers were gathered, if there was any type of process or understanding of what as being done, when a participant guessed the right or wrong answer or when a participant understood the activity and how to complete it but missed something by distraction, something that often times the same participant had done right in a previous task. In cases like this, I could attribute the participant error to a lapse of attention instead of it being a mistake caused by the visualizations and count the answer as correct. I could also see when a participant answered the right answer by guessing and count the answer to that task as wrong.

The video recordings could fill the gaps created by the voice and tasks answers that alone would give us a misguided view of the experiment results. This permitted me to further interpret the answers and create a revised set of answers that more accurately represented the participants understanding than the original answers of the task questionnaire. The Table 11 on the next chapter shows the revised set of answers. The detailed spreadsheet of answers explaining why each answer was changed can be accessed through the link on Appendix A.

I then used the Fisher's exact test on the revised results of the tasks questionnaire. The Fisher's exact test (FISHER, 1922) is recommended for finding if there are nonrandom associations in categorical data of small samples because it calculates the exact significance of the deviation from a null hypothesis using the p-value, instead of an approximation as other methods. It had to be used in this case because of the low number of samples in the data. The use of approximations could incur in the risk of the sample not following the used approximation, which would invalidate the tests.

The test was used to look for associations of the results obtained by the task questionnaire with aspects of the participants profile like age, previous knowledge on computational thinking, familiarity with the Code.org or similar platforms, experience on the field of education and experience in teaching computation thinking . I also applied the fisher's exact test to look for associations between the results on the tasks questionnaire and the SAM questionnaire, testing the three aspects of valence, arousal and dominance.

Lastly, I analyzed the suggestions the participants gave us in order to see if there was any enhancements or refinements that could be implemented in future works.

4.3.1   Threats to validity

A fundamental aspect regarding the results of an experiment is how valid they are (WOHLIN et al., 2012). I assessed four types of validity threats, as determined by Wohlin et al. (2012): internal, external, construction and conclusion.

Internal Validity: The threats to internal validity corresponds to unknown factors that may affect the result of a study. In order to minimize this threat, I used a profile

questionnaire that inquired about possible aspects of the participants experience, knowledge and habits that could have some influence or be relevant to the study. I also took into consideration the fatigue aspect, making the test session take no longer than an hour in order to exclude this aspect of our evaluation.

External Validity: The external validity is concerned with to what extent it is possible to generalize the findings. In order to minimize the threats to the external validity I gathered participants that represented a wide interval of ages and backgrounds. The participants had ages from 22 to 60 years old and had various levels of experience, knowledge of computational thinking and teaching experience, as shown in Table 10. I tried to represent as best as possible the population of teachers within the time constraints. I also had data of real students from 2 years before this study, which can be considered contemporary to the teachers that participated in our research.

Construct validity: Reflects to what extent the operational measures that are studied really represent what the researcher has in mind and what is investigated according to the research questions. It takes into consideration the relation between theory and observation. To mitigate the threats to this validity I discussed the tasks with an HCI specialist and minimized the carry-over effect from one task to another (FORSELL, 2010). I also made sure to elucidate all doubts of the participants regarding the understanding of the tasks, always making clear the intentions of each task so that the participants would understand what we wanted with each task, avoiding to get them answering questions that we did not make.

Conclusion validity: The ability to draw accurate conclusions from observations. This validity is concerned with the relationship between the treatment and the outcome. In order to minimize the threats on the conclusion validity (and also all of the other validity types (RUNESON et al., 2012)) we used the triangulation in our analysis. With the aid of the video recordings, the recorded speech of the participants and the questionnaires I could have a high degree of certainty regarding their understanding of the proposed visualizations, and the introduction to the study was made using the same slides and instructions for all participants link to slides. I also used the Fisher's exact test, which is adequate to this evaluation and number of participants, in order to investigate possible associations between participants characteristics and their understanding of the proposed visualizations.

5 Results

5.1 Profile Questionnaire Results

The results of the profile questionnaire can be ssen on the Table 10. There is a wide range of ages and levels of experience. Some teachers had experience teaching computational thinking and others not so much. In a broad analysis, almost all of the answers regarding profile aspect had a high variation. A common trait among almost all of the teachers was the high frequency of internet access.

5.2 Think Aloud Findings

In order tho analyze the the resulting data from the Think Aloud protocol, I used the process of Open Coding. First I watched all the video recordings and transcribed all the speech information that they had and at the same time we read and categorized all the speech into two categories: positive assertions and negative assertions. On the positive I included all the statements and expletives that indicated understanding. I then further divided the negative category into two other categories: Obstacles and barriers. Obstacles being the code that express solvable difficulties or problems in the process of understanding the visualizations. Barriers represented the problems or difficulties that remained unsolved for the participants, effectively halting their progress in a specific activity or aspect (LAZAR; FENG; HOCHHEISER, 2017). Table 9 shows an example of each classification.

I found a total of 85 codes: 46 being expressions of understanding, to which we attributed the color green, 32 obstacles represented by the color orange and 7 barriers, represented by the color red (Appendix A). The entirety of the open coding analysis can be seen in the link at Appendix A.

This result shows that the participants had more than half of their words expressing

Table 9 – Example of positive affirmations, obstacles and barriers gathered with open coding

Category	Speech
Positive affirmation	*Condensed Trajectory*..oh, here it shows all of the activities...
Obstacle	I am trying to understand these lines of code...
Barrier	Why did this only appears here?

Table 10 – Participants profiles - **Educational Level** - Graduation: (G), Post Graduation: (PG.), Pedagogy: (Pdgy) - **Electronic devices** - Computer: (C), Smartphone: (S), Tablet: (T) - **Apps** - Youtube: (YT), Scratch: (SC), Code: (C), Kan Academy: (KA), Moodle: (M) - **Where the apps are used** - Home: (H), School: (S), University: (U), Relative's House: (RH) - **Chart types** - Pie Chart: (PC), Line Chart: (LC), Bar Chart: (BC), Histogram: (H), Treemap: (TM),) Diagrams: (D), Net Chart: (NC), Infographics: (IF), Area Chart: (AC), Difference Chart: (DF)

Participant ID	Age	Educational Level	Teaching experience in years	How long knows about CT in years	How long taught CT in years	Weekly internet access	Electronic devices used	Apps used with educational purposes	Where the apps are used	Known chart types
P[1]	41 to 50	PG. Pdgy	9+	1 to 3	6 to 9	9+ times	Smartphone, Computer	SC, YT, M	H, S, U	PC, LC, BC, D
P[2]	41 to 50	G. Pdgy, Psychopedagogy	9+	1 to 3	1 to 3	9+ times	S, C, T	SC, YT	H, S	PC, LC, BC
P[3]	31 to 40	G. Pdgy	9+	6 to 9	1 to 3	9+ times	S, C, T	YT	H,S	PC, BC
P[4]	41 to 50	G. Pdgy	9+	6 to 9	Never taught	9+ times	S, C	YT	H	BC, NC
P[5]	31 to 40	G. Pdgy	9+	Does not know	Never taught	9+ times	S, C	YT	H, S	PC, BC
P[6]	41 to 50	G. Pdgy	9+	Does not know	Never taught	9+ times	C, T	YT, KA, M	H, S	PC, LC, BC, IF
P[7]	31 to 40	G. Pdgy	1 to 3	Less than 1	Never taught	9+ times	S, C	SC, YT	H, S	PC, BC
P[8]	22 to 30	G. Pdgy	1 to 3	Less than 1	Never taught	5 to 8 times	S, C, T	YT, M	H, S	LC
P[9]	41 to 50	PG. Science	9+	3 to 6	3 to 6	9+ times	S, C, T	C, SC, YT, KA	H, S	LC, BC, H, D
P[10]	31 to 40	PG. Pdgy	9+	1 to 3	Less than 1	9+ times	S, C, T	C, YT	S	PC, LC, BC
P[11]	31 to 40	G. Pdgy	9+	1 to 3	1 to 3	9+ times	S	Cw, YT	S	PC, LC, BC, D
P[12]	41 to 50	G. Pdgy	9+	3 to 6	3 to 6	9+ times	S, C	Code	H, S	LC, BC
P[13]	31 to 40	G. Pdgy	9+	6 to 9	3 to 6	9+ times	S, C, T	C, YT	H, S	PC, LC, BC, IF
P[14]	Over 50	G. Economic Science	9+	6 to 9	6 to 9	1 to 4 times	C	C, YT	H, S, RL	PC, LC, BC
P[15]	22 to 30	G. Pdgy	6 to 9	1 to 3	1 to 3	9+ times	S, C, T	C, YT	H, S	PC, LC, BC, IF, D
P[16]	31 to 40	G. Pdgy, Linguistics	9+	Less than 1	Less than 1	9+ times	S, C	C, YT	H, S	BC
P[17]	41 to 50	G. Pdgy	9+	Less than 1	Less than 1	9+ times	S, C	C, YT	H, S	PC, AC, LC, BC
P[18]	22 to 30	G. Pdgy	3 to 6	3 to 6	1 to 3	9+ times	S, C	C, YT	H, S, RL	PC, LC, BC, TM
P[19]	Over 50	G. Pdgy, Law	9+	1 to 3	Never taught	9+ times	S, C, T	YT	H, S, RL	PC, LC, BC, IF
P[20]	Over 50	G. Pdgy, Biology, PG. Didatic and Psychopedagogy	9+	Less than 1	Never taught	9+ times	S, C, T	None	None	PC, AC, LC, DC, D, TM

understanding. It also shows that in spite of several obstacles, the participants were usually able to work around or understand the problems they found, and last, the 7 barriers show that the visualizations proposed can be further improved by removing these barriers or at least making them easier for the users to transpose.

5.3   SAM, Profile and Tasks Questionnaire Findings

After getting the results of the task questionnaire, I watched the video recordings in order to make sure that the answers reflected the real understanding of the participants. After watching all the video recordings, I altered the initial questionnaire answers based on the actions of each user. Tasks that were answered correctly through guessing had their answered changed to "wrong". Tasks that were answered incorrectly due to the user misreading the question or due to simple lack of attention unrelated to problems with the visualization were changed to "correct". Table 11 shows in green the answers that were originally correct and red the answers that were originally wrong. On yellow we have the answers that were changed to "correct" and in orange we have answers that were changed to "wrong". The Table 11 of revised answers reflects more accurately the understanding of the participants than the initial results gathered by the task questionnaire result alone, which is why it was used in the search for associations with the participants profile characteristics as detailed following paragraphs. The reason each of the answers were changed can be found at the spreadsheet link on Appendix A.

As soon as the participants completed the tasks, I would request that they answer the SAM questionnaire (BRADLEY; LANG, 1994). The SAM questionnaire has three categories designed to evaluate how the participant felt. The three fields are *valence*, *arousal*, and *dominance*. Each of these categories should be rated from 1 to 9, denoting the level of each category that the participant experienced during the experiment. As the Figure 23 shows, both the *valence* and *arousal*aspects remain fairly close in the score amplitude and median. We can see, however, that this is not the case with the *dominance* aspect. The dominance aspect is much lower on the score scale. With that in mind we can conclude that the participants felt a lower level of dominance over the proposed visualizations.

Another interesting aspect shown by the Figure 23 is the outlier on the lowest value of the arousal aspect. This was analyzed following Hammer and Sikorski (2015) idea of the importance of outliers. The particular participant that gave that score also had a low value on the dominance aspect, putting a higher value on the valence aspect. The participant had a low overall understanding of the visualization, shown in the video recording and in the results of the task questionnaire. This may suggest the that the participant did not feel motivated and felt intimidated by the visualizations. The dominance aspect was

Table 11 – Revised answers of the task questionnaire. Green represents originally correct answers. Red represents originally wrong answers. Yellow represents originally wrong answers changed to correct. Orange represents originally correct answers changed to wrong.

Participant	Tasks									Total
	1	2	3	4	5	6	7	8	9	
1	0	0	0	0	1	0	1	0	1	3
2	1	1	1	0	1	1	1	1	1	8
3	0	0	0	0	0	0	0	0	0	0
4	0	1	1	0	0	0	1	1	1	5
5	0	0	1	0	0	1	0	0	0	2
6	1	0	1	0	1	1	1	1	1	7
7	1	1	1	1	1	1	0	1	1	8
8	1	1	1	0	1	1	1	1	1	8
9	0	1	1	1	1	1	1	1	1	8
10	0	1	1	1	1	1	1	1	1	8
11	1	1	1	1	1	1	1	1	1	9
12	0	0	1	1	1	1	1	1	1	7
13	0	1	1	1	1	1	1	0	0	6
14	0	0	1	0	0	0	0	0	0	1
15	0	1	1	0	1	1	1	1	1	7
16	0	1	1	1	1	1	1	1	1	8
17	1	1	1	1	1	1	1	1	1	9
18	1	1	1	1	1	1	1	1	1	9
19	1	1	1	1	1	1	1	1	1	9
20	1	1	1	1	1	1	1	1	1	9

lower in general, but this particular participant also felt a low level of arousal, which was uncommon on the results. This seems to corroborate the result found on the Fisher's exact test, implying that there may be an association between the arousal level and the understanding of at least some of the tasks, as it happens with task 11 shown in the following analysis.

Aiming to find if there were nonrandom associations between the results of the test and the profile of the users, I divided the participants in two categories. Using the revised answers to the tasks that I compiled by watching the videos and triangulating the image with the speech and actions of the participants, I gathered a list of answers that was more accurate than the unaltered tasks questionnaire result, as it reflected more realistically the understanding of each participant. By changing the classification of right and wrong answers according to the understanding of the users (section 4.3), I could gather answers that were more faithful to the level of understanding each participant had. I divided the participants into the ones that scored 0 through 4 and the ones who scored more than 5 points on the tasks questionnaire. The revised answers of the task questionnaire
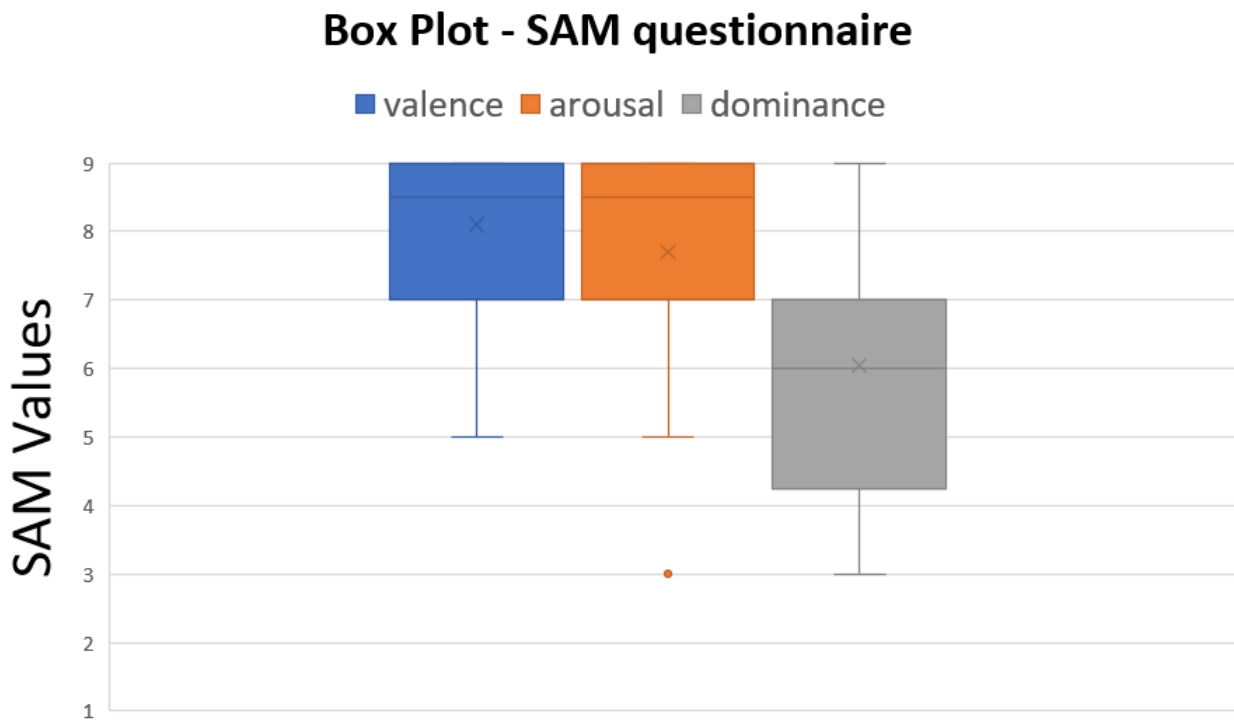
Figure 23 – SAM Questionnaire Box Plot

were chosen because it represents in a lot of ways the measure of understanding that the participant had while using the visualizations. I then used the Fisher exact test, having the two tasks questionnaire score ranges as categorical values and some aspects of the participants profiles in order to investigate the obtained results.

I divided the participants in two categories using 8 different aspects, being 5 profile aspects and 3 aspects being the SAM questionnaire aspects. The aspects were:

- Age (less than 40 years old \more than 40 years old)

- Familiarity with visual programming tool like *Code.org* or *Scratch* (had familiarity \did not have familiarity)

- Previous work experience as a teacher (more than 9 years of experience \less than 9 years of experience)

- Previous knowledge about charts (knows more than 3 types charts \knows less than 3 types of charts)

- Prior experience in teaching computational thinking (never taught computational thinking \already taught computational thinking)

- *Valence* (1 to 5 points \6 to 9 points)

- *Arousal* (1 to 5 points \6 to 9 points)

- *Dominance* (1 to 5 points \6 to 9 points)

For each of the aforementioned categories I used the Fisher's exact test in order to look for nonrandom associations between each category and the task questionnaire score which represented the measure of the participant's understanding of the visualizations. For each test I created a null hypothesis and an alternate hypothesis. The Table 12 shows the hypothesis and the p-values obtained. We used a confidence interval of 95% due to the sample size.

Table 12 – Null and alternate hypothesis of task questionnaire score and profile and SAM aspects. The blue color denotes the accepted hypothesis at a confidence interval of 95%.

Null Hypothesis - H0	Alternate Hypothesis - H1	P-values
There is not an association between the task score and the participant's age	*There is an association between the task score and the participant's age*	0.5913
There is not an association between the task score and the participant's familiarity with the Code or similar tools	*There is an association between the task score and the participant's familiarity with the Code.org or similar tools*	0.5868
There is not an association between the task score and the participant's prior teaching experience	*There is an association between the task score and the participant's prior teaching experience*	0.5377
There is not an association between the task score and the participant's prior knowledge of charts	*There is an association between the task score and the participant's prior knowledge of charts*	0.5820
There is not an association between the task score and the participant's prior experience in teaching computational thinking	There is an association between the task score and the participant's prior experience in teaching computational thinking	1
There is not an association between the task score and the participant's self attributed valence	*There is an association between the task score and the participant's self attributed valence*	0.2000
There is not an association between the task score and the participant's self attributed arousal	*There is an association between the task score and the participant's self attributed arousal*	0.0035
There is not an association between the task score and the participant's self attributed dominance	*There is an association between the task score and the participant's self attributed dominance*	0.2553

The Fisher's exact test did not show any non-random association between the profile aspects and the revised result of the task questionnaire. However an association was found regarding the participants level of arousal and their understanding of the visualizations.

The tasks questionnaire was paramount for the analysis and results. This questionnaire enabled me to track what the user was doing at every moment. As I knew what they were looking for, I could better understand their actions and interactions by knowing what intent guided them. As I also knew which kind of interactions every activity required, I knew which kind of interactions should have been happening and what interactions actually happened. Together with the result of this questionnaire I could better understand what kinds of interactions and representational problems the participants were having. By comparing the number of correct answers on each activity, I found out which of them had the lower scores and what types of interactions were necessary to correctly answer those activities. I found out the the activity number one and number four had a only 45% and 55% rate of correct answers respectively, far lower than the average of 70% . I decided to make a deeper analysis regarding these two activities and look for the reasons why the rate of correct answers was lower on those two cases.

I applied the Fisher's exact test categorizing the participants into *"participants who chose the right answer"* and *"participants who chose the wrong answer"*, and compared this categorization to other aspects of the profile of each participant. I then formulated a null hypothesis and an alternate hypothesis for each of those categories as shown in Table 13. Also on Table 13 I present the values of the p-values found on each of the Fisher's exact test for each aforementioned category. Using again a 95% confidence interval I found no association between those categories and the right or wrong answers on activity one.

All of our tests between the results of task one and profile and SAM aspects indicated no association between them.

I also tested the task four results with the same profile aspects of task one, hoping to find some association between the participants profile and their answers to the activity. The Table 14 details the nul and alternate hypothesis and the p-values we found with Fisher's exact test using a 95% confidence interval. The tests shows that in all of the 8 categories that were tested for the existence of an association between these categories all of the p-values were insufficient to disprove the null Hypothesis, leading to the conclusion that there there is no association between the answers in the activity four and the characteristics of the participants profiles.

As the results of the Fisher's exact test (FISHER, 1922) showed no clues for the results we had on activity one and four, I searched for other reasons that could explain

Table 13 − Null and alternate hypothesis of activity one. The blue color denotes the accepted hypothesis at a confidence interval of 95%.

Null Hypothesis - H0	Alternate Hypothesis - H1	P-values
There is not an association between answering the question 1 correctly and the participant's age	*There is an association between answering the question 1 correctly and the participant's age*	1
There is not an association between answering the question 1 correctly and the participant's familiarity with the Code.org or similar tools	*There is an association between answering the question 1 correctly and the participant's familiarity with the Code.org or similar tools*	0.6424
There is not an association between answering the question 1 correctly and the participant's prior teaching experience	*There is an association between answering the question 1 correctly and the participant's prior teaching experience*	0.2848
There is not an association between answering the question 1 correctly and the participant's prior knowledge of charts	*There is an association between answering the question 1 correctly and the participant's prior knowledge of charts*	0.3698
There is not an association between answering the question 1 correctly and the participant's prior experience in teaching computational thinking	There is an association between answering the question 1 correctly and the participant's prior experience in teaching computational thinking	0.1597
There is not an association between answering the question 1 correctly and the participant's self attributed valence	*There is an association between answering the question 1 correctly and the participant's self attributed valence*	1
There is not an association between answering the question 1 correctly and the participant's self attributed arousal	*There is an association between answering the question 1 correctly and the participant's self attributed arousal*	0.2148
There is not an association between answering the question 1 correctly and the participant's self attributed dominance	*There is an association between answering the question 1 correctly and the participant's self attributed dominance*	0.6699

Table 14 – Null and alternate hypothesis of activity four. The blue color denotes the accepted hypothesis at a confidence interval of 95%.

Null Hypothesis - H0	Alternate Hypothesis - H1	P-values
There is not an association between answering the activity 4 correctly and the participant's age	*There is an association between answering the activity 4 correctly and the participant's age*	1
There is not an association between answering the activity 4 correctly and the participant's familiarity with the Code.org or similar tools	*There is an association between answering the activity 4 correctly and the participant's familiarity with the Code.org or similar tools*	0.1597
There is not an association between answering the activity 4 correctly and the participant's prior teaching experience	*There is an association between answering the activity 4 correctly and the participant's prior teaching experience*	1
There is not an association between answering the activity 4 correctly and the participant's prior knowledge of charts	*There is an association between answering the activity 1 correctly and the participant's prior knowledge of charts*	0.3698
There is not an association between answering the activity 4 correctly and the participant's prior experience in teaching computational thinking	*There is an association between answering the activity 4 correctly and the participant's prior experience in teaching computational thinking*	0.6424
There is not an association between answering the activity 4 correctly and the participant's self attributed valence	*There is an association between answering the activity 4 correctly and the participant's self attributed valence*	0.4500
There is not an association between answering the activity 4 correctly and the participant's self attributed arousal	*There is an association between answering the question 4 correctly and the participant's self attributed arousal*	0.0737
There is not an association between answering the activity 4 correctly and the participant's self attributed dominance	*There is an association between answering the activity 4 correctly and the participant's self attributed dominance*	0.3618

the larger number of wrong answers on these two activities. I watched again all the videos of the participants focusing on the activities one and four, in order to investigate if the difficulty was in the interaction aspect or in the interpretation aspect of the visualizations. The results of the investigation are discussed in the next chapter.

5.3.1   Participants Feedback

Regarding the participants opinion, I prepared two questions for each participant to answer. *Question 1: "Would you want to change anything in the visualizations?"* and *Question 2: "Do you have any comments regarding the visualizations?"*. The questions were optional, so the participant could left them in black if they did not have any opinion.

The *Question 1* got a total of 20 answers. On 15 of them, the participants did not express any wish in changing any aspect of the proposed visualizations. We also had 5 positive answers suggesting changes on the visualizations, listed on Table 15.

Table 15 − Participants Suggestions

Number of Answers	Suggestion
5 suggestions	[P2] - *"Sometimes the scroll bar could not be seen the entire time. And also the color look very alike sometimes."*
	[P9] - *"Maybe a radar chart could be added to indicate the dominance of the students over different concepts."*
	[P16] - *"There should be a field with the total number of tries of each student, so we don't have to count."*
	[P18] - *"Do some changes in the Complete Trajectory when there are more than one student."*
	[P19]-*"When we are analyzing one student, the graph should be bigger."*

The *Question 2* got a total of 20 answers listed on Table 16. Some participants had mixed feelings expressed on their comments, so we highlighted them by using colors. Green text shows appreciation, red show negative opinion and orange are suggestions made in the comments.

Table 16 – Participants Comments

Number of Answers	Comment
16 comments, 12 positive, 6 suggestions and 4 negative	[P2] - *"I found it interesting,* and i suggest for us to be able to select two activities and have the time between them."
	[P4] - *"Interesting* but difficult."
	[P5] - *"Interesting."*
	[P6] - *"Hard to see."*
	[P7] - *"I found it well explained and with all the necessary information, especially the Condensed Trajectory that shows us in a faster way."*
	[P8] - *"It looked great."*
	[P9] - *"I liked the possibility to visualize the performance of the students through this charts. We can highlight the students that are having difficulties and also the ones that aren't.* On the *Complete Trajectory,* it is important to have a way to differentiate the students that occupy the same position on the x a y axis. Also, removing a student and inserting the same one needs to be fixed so we don't have to add another student before adding the previously erased student."
	[P11] - *"I liked to participate on this visualization proposal."*
	[P12] - "Seems hard at first, but it gets easier as we get used to it."
	[P13] - *"I liked the charts a lot, found it easy to comprehend and interact* but I did not use the *Condensed Trajectory,* it wasn't necessary to go over that chart."
	[P14] - *"I liked it and found the way the charts shows the information to the teachers to be very didactic."*
	[P15] - *"I had many doubts regarding the charts interpretation.* It is necessary some kind of training in order to use it properly."
	[P17] - *"I found it very interesting, the teacher that has the privilege of using the system will be able to evaluate the students development in a clear and objective way, being able to solve possible difficulties of the students."*
	[P18] - *"The charts are nice to look at and you can have a good visualization* but when you compare students it gets a little crowded. It is hard for me to see."
	[P19] - *"I would like to better dominate the available tools."*
	[P20] - *"I would like to have the questionnaire beside the charts in order to make it easy to remember the tasks."*

5.4 Discussion

On this section I discuss the results, the evaluation observations and results.

As I conducted the evaluation of the visualization of the learning trajectories, I was able to observe several interesting bits of information and make some inferences in a couple of aspects.

5.4.1 Think aloud protocol usage

As observed by Lewis (1993), frequently the participants would stop talking without being "pushed" a bit, and even so, some will remained in silence. Others would resort to only describe what they are doing instead of what they are thinking, or keep alternating between these two actions. On the other hand, the presence of two or more participants

in the same room created a kind of group environment where the participants tried to interact between them and solve the tasks together, providing each other with tips and information remarks. As the tasks were planned to be solved individually, I separated the participants further and asked them to avoid this king of interaction, at least in the aspect of providing information to the other participants.

5.4.2 Evaluation results and profile aspects

During the analysis, I found only an association between the level of arousal and the tasks score result. All the other profile factors like age, previous experience in teaching, knowledge of charts, prior experience on teaching computational thinking were found to have no association with the tasks questionnaire results. This may indicate that some other profile or psychological aspect of the participants or a combination of such aspects not measured in this study had influence over the overall result of each participant.

Considering the SAM questionnaire results, I noted a lower level of overall dominance between the participants. This may suggest that the participants felt intimidated by the new visualization. I noticed after the evaluation that several of the participants seemed uncomfortable at the beginning, a feeling that seemed to dissipate as the participant concluded the proposed activities and started to know more of the interaction aspects of the visualizations. Even though they seemed to be more comfortable at the end, the feeling of intimidation or not being in control was present enough for this aspect to have a lower level in general. The other aspects of the SAM questionnaire were higher, showing that the participants did not feel bored or sleepy (arousal) nor felt dissatisfied with the experiment (valence) (BRADLEY; LANG, 1994).

Making a deeper analysis of the interaction aspects, I found that most of the participants were able to interact with the visualizations in a satisfactory way. Not all visualizations were required to correctly answer all the tasks. The participant could answer all of proposed tasks with only the *Complete Trajectory* or the trajectories of each activity. The *Condensed Trajectory* had less information and could not solely be used to answer all of the questions, in spite of offering a apparently more comprehensive visualization of the students complete learning trajectory in the eyes of the participants. It is interesting to note that some participants indeed used only one form of the visualizations to solve all of the activities, while others explored the visualizations in order to find the easier way to answer each activity. The learning trajectories focusing only on single activity was the most used form of visualization, followed by the *Condensed Trajectory* and the *Complete trajectory.*

The filtering options on panel 3 and 4 were rarely used, as the participants seemed more familiarized with the "x" to exclude unwanted students in order to focus into a single one. Of the seven presented interaction categories a total of 6 were used in the proposed

visualizations with the exception being the "Encode" category, which would implicate on giving more freedom to the user on altering color, shapes and size of the data elements. The most widely interaction category used by all of the participants were the "Select" and "Explore", which consisted in adding and excluding students from the visualizations and the "Filter" which consisted of choosing a single activity and "Connect" which was accessed through the action of hovering the mouse on top of the graphical elements. All of the participants used these four interactions. The least used interaction categories were the "Reconfigure", which consisted for example in accessing the *Condensed Trajectory*, and the "Abstract\Elaborate" which consisted in clicking on a vertex of the trajectories graph in order to see the students code. As some participants never used the *Condensed Trajectory* nor clicked the vertices, some of them concluded the experiment without ever using these kinds of interactions. By not clicking on the vertices to see the code, some participants never accessed the third layer of information present on the visualizations.

Another curious aspect is that on the contrary of what is stated by Fouh, Akbar and Shaffer (2012), the animation of the learning trajectories failed most of the times in giving the participant the feeling of the dynamic of the learning trajectory. The idea of a sequence of actions came not from the animation, but form the conjectures of the very participants as they explored the visualization and noted the timestamps of each try and the legends of each axis of the charts. One can infer that the fast and simple animation was not enough to be perceived as a piece of information. Maybe if the animations were more complex like perhaps showing a student walking over his trajectory as it is being drawn in the panel would better convey the idea of the student traveling that path.

One of the problems reported and noted by me as I watched the videos was the overlapping of vertices on the learning trajectories charts. When two students tried some activity they would sometimes have vertices of their learning trajectories occupying the same space. This problem was mitigated by the ability to bring the learning trajectory of the chosen student to the top layer of the visualization as the user clicked on the student's name. There were however situations that the overlapping wasn't noticed by the participant, in cases where the student had a single try that was covered up by the trajectory of another student. This led to some errors and confusion on some of the activities, depending on the order the participant added the students. This problem did not occur in the *Condensed Trajectories* due to the more spaced nature of our proposed visualization. The evaluation did not required that the participant examined overlapping bubbles, although they did occur in some student combinations. This do not poses a problem in the *Condensed Trajectory* because the bubbles are slightly transparent and separated, so the user can see that there are more than one bubble sharing the same space.

In general the *Complete Trajectory* graph, in spite of having all the information condensed into one single visualization, was the least used visualization of the proposed

ones. Its often long extension required frequent scrolling and the addition of new students saturated the visual field very quickly, rendering it ineffective (NASCIMENTO; FERREIRA, 2005) if used with more than two or three students. In this case apparently the layers of separation mentioned by Mazza (2009) of only one aspect (color) was not enough to properly distinguish long learning trajectories. The learning trajectory of a single activity however provided a more effective visualization, allowing the participant to quickly see and compare different trajectories of different students. The *Condensed Trajectory*, representing the trajectory of the student also provided an effective visualization for the participants that explored it, even inspiring some of them to praise it. It permitted the participants to quickly see difference in number of tries in each activity, detect possible outliers and missing activities.

I discovered, regarding the task one, where the participant was asked to find which of the three specified students had done the activity 6 correctly, that all of the participants were able to add the required students and choose the right activity on the visualization. Of the 11 participants that did not answered correctly, 6 of them were able to access the third layer of the visualization and see the code written by the students, but were unable to interpret it the right way. The other 5 participants that did not answer correctly did not access the third layer of the visualization.

I came to the conclusion that these students were unable to interpret the graph at that moment, either on what it meant or the order that each student tried to solve the activity, or were unable to connect the students trajectories with the "right number of lines" line present in the graph. It is important to notice that this line indicates only the right number of lines of code to answer an activity correctly. A student may have written this number of lines but not in the right order or not the right lines, so this line does not guarantee that the vertices that are on the same level as it to be necessarily correct. It is necessary for the teacher to access the code of the student in order to check if his answer is correct.

Some of the participants judged that once on that line a student would have answered correctly. Some plainly ignored the "correct number of lines" line, others even looked at the code but did not connect or correlate the correct code and the student's code and the position of the vertices of the trajectories with the fact that the student answered correctly or not. The easiest way to solve the activity one was through the visualization on Figure 24. We can see that two students have vertices with the same number of lines of code as the correct answer. If we access their code though, we can see that only one of them has the right code (Figure 26), while the other one did not, having only the correct number of lines (Figure 25). So, to put it simply, the problem was more of a matter of interpretation in the sense of connecting the data than the inability to access information.

Regarding the task four, the participant was asked to add three students to the
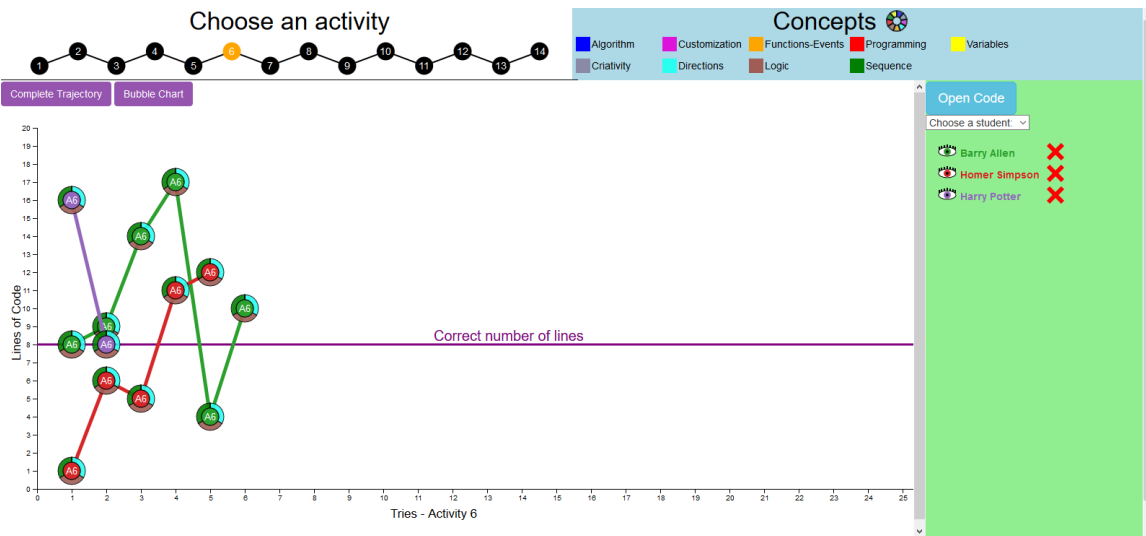
Figure 24 − *Single Activity Trajectory* with the students mentioned on task 1
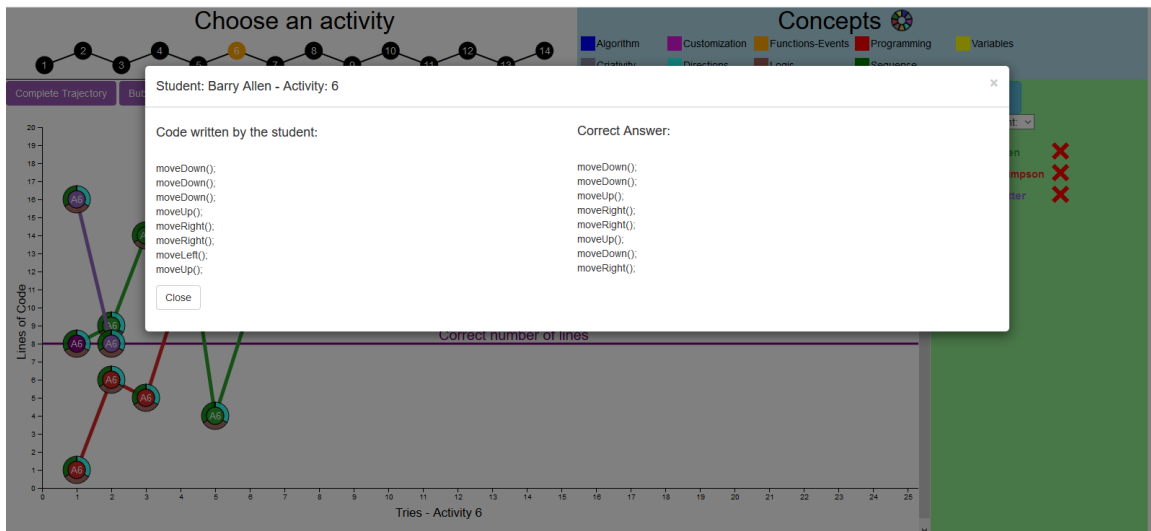
Figure 25 − Modal showing the incorrect code of the Barry Allen student
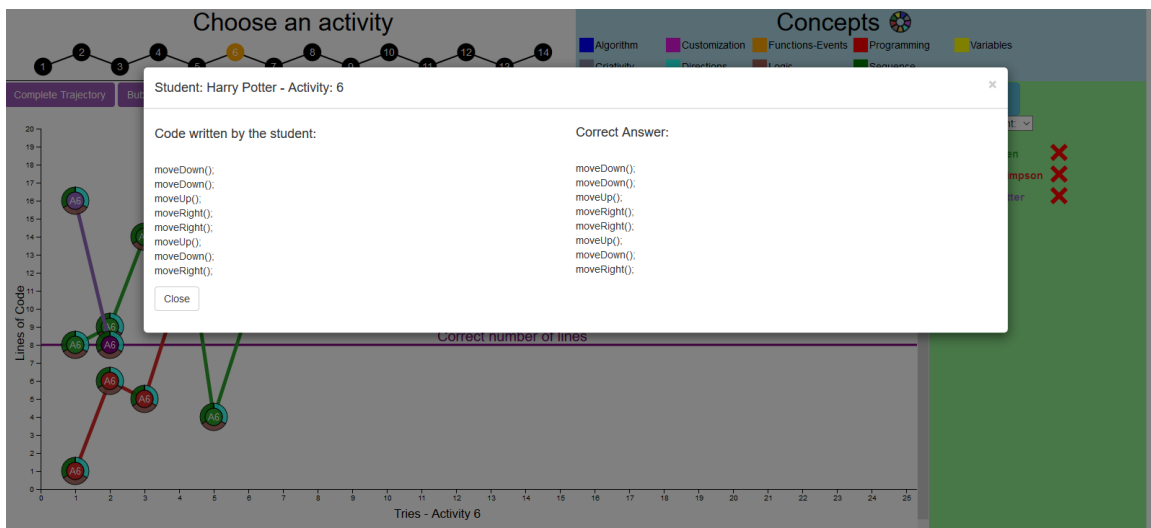
Figure 26 − Modal showing the correct code of the Harry Potter student

visualization and answer which of them had done all the activities. It was specified for the participants that even if the activity was not answered correctly, it would count as if the student had done it. If the student did not made any tries on some activity, then it would be considered that he or she had not done that activity. I analyzed the videos once more and discovered that all of the participants could get to the necessary state of the visualization in order to get the right answer. Every participant could add the right students at the *Complete Trajectory*, but 9 were unable to analyze it visually to know which activities were missing for each student. Some of these 9 participants even explored the *Condensed Trajectory* with the right students added (Figure 27) and still missed the fact that some of the bubbles were missing, indicating no tries on those activities. Since there were no more interactions needed in order to get the information out of the visualization, I conclude that it was also a matter of interpretation and the lack of connecting the presented information that prevented all he participants to reach the right answer.
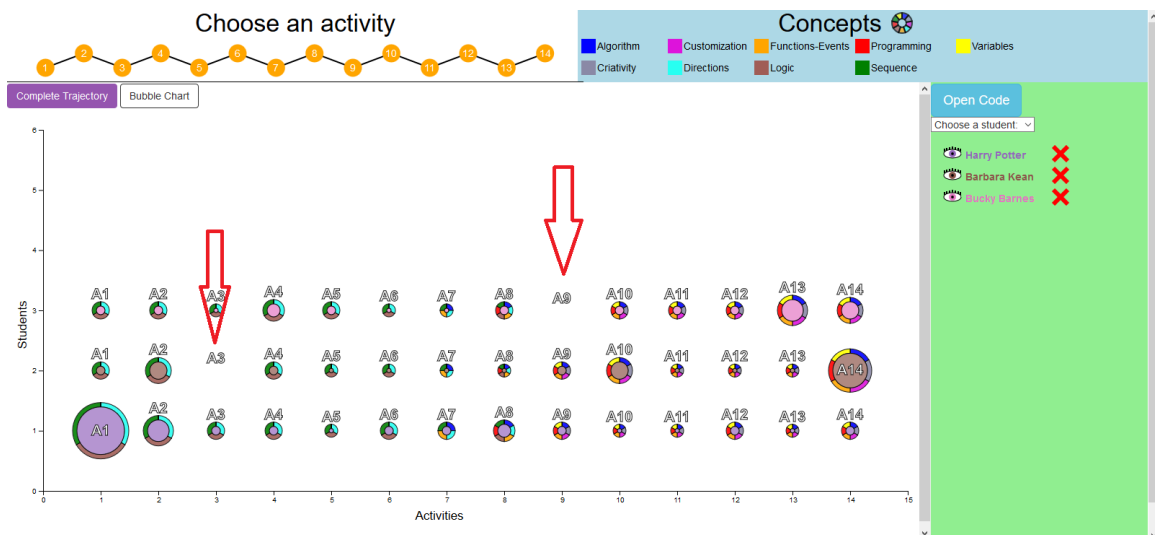
Figure 27 – *Condensed Trajectory* showing all the activities of the selected students. The red arrows indicate which activities are missing.

5.4.3   Participant behavior during the experiment

During the introduction of the experiment, the participants were often inattentive regarding the instructions which had to be repeated and reinforced throughout the experiment. The participants in spite of being teachers lacked "discipline" in hearing the instructions and were mostly intimidated at first (this notion is reinforced by the lower overall dominance score of the SAM questionnaire). As the experiment progressed they seemed to be getting more comfortable with the interaction aspect of the visualizations and their visual interpretation of the visualizations became faster and more accurate, and by the end they seemed to be much more comfortable with the visualizations, even finding it amusing, as some of comments suggests. Most of the participants used most of their time on the first three tasks and only a fraction of it to complete the last tasks. Three

of the initial 23 participants however did not use the visualizations, only answering the questionnaires. As they did not use the proposed visualizations, I had no choice but to exclude them from the experiment.

5.4.4   Visualization Refinements

After the evaluation I made small improvements in the visualizations. I fixed an issue that prevented the user of adding the same student to the visualizations right after deleting it. The user would have to insert another student before reinserting the erased student. I also added a highlight function in all interactive elements of the visualizations, even in the the panel 3 and 4, so when the user hovers the mouse over the elements the background of the selected element changes color, indicating that there is a possibility of some kind of interaction which was only previously indicated by the tool tips.

6 Conclusion

This study proposed three new, yet literature based visualizations of learning trajectories that heavily rely on interactions. These proposed visualizations were later used to represent a data set collected on a school with 48 students through the use of the *Code.org* site and activities. This data was organized in learning trajectories that visually showed the progress of the students while doing the *Code.org*. Then these representations were showed to a group of 23 teachers who worked with elementary education.

By analyzing the results of the usability evaluation I came to some conclusions:

- The proposed visualizations were able to convey most of what we wanted in a first moment with only the basic information passed to the teachers, having an average of of 72% rating of comprehension.

- The proposed "complete learning trajectory" visualization is often too long and confusing in spite of presenting the most information. By Nascimento and Ferreira (2005) terms, it is an expressive visualization but not very effective.

- The learning trajectory of only a single activity at a time is a much easier way to analyze and compare the data of the students

- The *Condensed Trajectory* representing the learning trajectories offers an easier and more comprehensible way of presenting learning trajectories that are very long.

- Concise representations such as the *Condensed Trajectory* and the *Single Activity Trajectory* seem to works best. Using Nascimento and Ferreira (2005) terms, a little expressiveness can be traded for a lot more effectiveness.

- Short and discrete animations were not able to convey the idea of linearity or sequence to the participants. A more complex and detailed animation is perhaps necessary in order to do so.

- The aspect of interpretation and connection between the data can be improved. By identifying and highlighting which students have answered the activities correctly and which students skipped some activities we can facilitate the work of the teacher without them having to do much exploration in this sense.

6.1 Precision vs realism

Giving the nature of the conducted experiment, classified according to Carpendale (2008) as a Laboratory experiment, this study has a high degree of precision, giving that

it's procedures were planned in it's entirety and I knew when and where the behaviors of interest could happen. In addition to that, some non-realistic behavior was used in the form of the think aloud protocol, which adds to the precision aspect but takes away a great part the realism.

6.2   Contributions

The contributions of this work are the proposed visualizations. With their solid literature basis and success in conveying most of the information swiftly to teachers that had never worked with them in less than an hour, they stand out as the main contribution of this work. They may be extended in order to be used by other teachers and in other areas besides the teaching of computational thinking.

The visualization presented in layers of visual representation and data accessed through interaction coupled with the generic interaction categories proposed by Yi et al. (2007) is also a contribution since safe for vague mentions of layers in some papers there seems to be nothing like it in the ways of organizing the visualization components and data.

The teachers and educators point of view and feedback regarding the visualizations is another valuable contribution, since there are very few papers that focuses on the visual aspect of the learning trajectories (CARMO; GASPARINI; OLIVEIRA, 2019).

6.3   Future Work

In spite of being well accepted, the participants of this study had some observation and suggestions regarding the proposed visualizations. Through the suggestions and comments and with the observations made during the study, I compiled some improvements that could be implemented in the future. Such improvements include:

- Make sure the scroll bar is always visible no matter the size of the screen.

- Differentiate the students by more than just color, as some participants found that some colors look alike and it becomes more difficult to differentiate colors once the number of students begins to rise.

- Increase the size of the charts according to the user preferences.

- Selection of more than just one activity at a time

- Indication to the user when there is overlapping on the learning trajectories

- indication of when student answered an activity correctly, improving by this the connection aspect between the data.

- indication of which activities were skipped by the students, also improving the connection aspect of the data.

Of the listed improvements, the most important one seems to be the overlapping one because in some cases it can hide information without the user noticing. This suggestion actually evokes a problem in the way the information is presented, while the other ones do not affect the visual presentation of data so strongly, being more of a facilitator kind of suggestions. The way to solve this problem is not yet clear, but some kind of warning or marking that could notify the user that there are some data in the same location would seem to solve this issue.

It is also very important to improve the connection between data, by indicating things such as the correct answer of a student or the skipped activity of a student. Since this two aspects were the ones that produced more confusion, it seems important to present this kind of association or connection in order to facilitate the teachers understanding because they are possible to be done using machine algorithms. This way the can use their time to look for associations that are harder to detect with only machine algorithms

One last consideration regarding the suggestions is that the redundancies in the differentiation of data are also important as some people are incapable of discerning some colors as stated by Silva (2014) and by some of the participants, so the implementation of this suggestion could increase the accessibility aspect the proposed visualizations.

As future work, a second usability evaluation incorporating the users feedback and the previously mentioned improvements on the proposed visualizations could be enlightening. By comparing the teachers understanding results of this study with a second one with all the visualization improvements implemented, one could effectively measure the level of understanding this improvements would bring to the proposed visualizations.

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APPENDIX A – Links - questionnaires, slide presentation and open coding analysis

A.1 Questionnaires

Profile (original portuguese version) - <https://tinyurl.com/y5m7lnk3>

Tasks (original portuguese version) - <https://tinyurl.com/yyshowal>

SAM (original portuguese version) - <https://tinyurl.com/y59as4qj>

A.2 Open Coding Analysis

<https://tinyurl.com/y8jq7kpn>

A.3 Slides for the presentation of the study

<https://tinyurl.com/yybrl8hg>

A.4 Revised task questionnaire results

<https://tinyurl.com/yc7hnoa3>

A.5 Usability Evaluation Videos

<https://tinyurl.com/ydad8prw>

A.6 Project and authorization forms sent to the ethics committee

Projeto de Mestrado

Programa de Pós-graduação em Ciência da Computação

Avaliação de visualizações de trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação

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Orientador: Profa. Dra. Luciana Aparecida Martinez Zaina[2]

Março de 2018 a Fevereiro de 2020

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Resumo

Com a adoção crescente do ensino computacional em diversos países e o surgimento de novas maneiras de se trabalhar o ensino computacional, torna-se cada vez mais necessário o entendimento dos conceitos chave do processo de aprendizado dos alunos. A fim de se obter um melhor entendimento de do processo de aprendizagem e melhorar a maneira de exposição de tais conceitos têm-se as trilhas de aprendizagem, caminhos virtuais para o desenvolvimento intelectual que promovem e desenvolvem competências. As trilhas permitem que profissionais na área da educação analisem e avaliem o progresso do aluno e possam visualizar o caminho do aprendizado e até mesmo antecipar problemas futuros no processo de ensino. Este projeto de pesquisa visa realizar uma avaliação de visualizações que apresentem trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação. Uma vez geradas, as visualização terão sua usabilidade avaliada por um grupo de estudo composto por professores do ensino básico, alunos de graduação e pós graduação em pedagogia que permitirão a melhora do conjunto de recomendações usadas na criação de visualizações mais aderentes ás necessidades dos professores.

1 Introdução

A evolução dos computadores teve grande influência em várias ciências. Com sua capacidade cada vez maior de tratar e analisar grandes conjuntos de dados, realizar explorações e extrair significados, a computação, sua utilização e seu ensino tornaram-se novos campos de pesquisa e aprendizado[15].

Devido à integração da computação no auxílio no processo científico e no desenvolvimento de outras ciências e sua importância crescente como ciência em si, o ensino computacional passou a ganhar mais importância nos programas curriculares de diversas escolas[15, 17, 18]. Entende-se por pensamento computacional a capacidade de analisar, sistematizar, representar e resolver problemas[15].

Diversos países, como por Alemanha, Argentina, Austrália, Coreia do Sul, Escócia, França, Inglaterra, Estados Unidos da América, Finlândia, Grécia, Índia, Israel, Japão, e Nova Zelândia, entre outros, passaram a adotar o ensino da computação nas escolas a fim de desenvolver habilidades relacionadas à compreensão e fluência no mundo digital assim como resolução de problemas complexos [15]. À medida que novas maneiras de se trabalhar o ensino computacional

1

foram surgindo, foi tornando-se cada vez mais necessário o entendimento dos conceitos chave que são essenciais para o aprendizado dos alunos[12, 15, 17, 18, 23].

De forma a entender o trajeto de aprendizado dos alunos e melhorar a maneira de exposição dos conceitos a serem ensinados surgiram as trilhas ou trajetórias de aprendizagem. Trilhas de aprendizagem, de acordo com Tafner [22] são caminhos virtuais para o desenvolvimento intelectual que promovem e desenvolvem competências. Essas trilhas ou trajetórias são consideradas sob dois pontos de vista: sendo aquela percorrida pelo aluno durante sua interação com os recursos disponibilizados ou a sequência de conteúdo e atividades definidas pelo professor ao planejar sua disciplina [16]. As trilhas permitem que profissionais na área da educação analisem e avaliem o progresso do aluno e possam visualizar o caminho do aprendizado e até mesmo antecipar problemas futuros no processo de ensino [2, 13, 17, 18].

A utilização dos computadores se dá das mais variadas formas, mas geralmente atuam ampliando as capacidades cognitivas humanas, estendendo sua memória e capacidade na execução de tarefas programáveis [14]. No contexto das trajetórias de aprendizagem, a visualização ganha uma grande importância na análise e exploração visual dos resultados e trajetórias obtidas [10, 14].

Visualização pode ser entendido como o processo de se transformar algo abstrato em imagens de maneira a serem vistas por seres humanos [14]. Nascimento & Ferreira [14] afirmam que o objetivo de uma visualização é auxiliar no entendimento de determinado assunto, o qual exigiria maior esforço para ser compreendido sem uma visualização. Utilizando-se da exploração visual, profissionais podem interagir diretamente com os dados e aplicar seu discernimento a fim de se extrair conclusões [6, 10, 14].

Através de visualizações focadas em demonstrar as trilhas de aprendizado, o processo do ensino e aprendizado do pensamento computacional pode ser melhor entendido e estudado. Dessa forma, pode-se buscar melhoras ou ajustes nos métodos de ensino de acordo com as introspecções e conclusões geradas com a ajuda de tais visualizações.

Este projeto de pesquisa objetiva avaliar diferentes tipos de visualizações de trajetórias de aprendizado relacionadas com aprendizado de pensamento computacional com foco em programação. Com a colaboração de professores do ensino fundamental I, o projeto visa obter uma classificação de comunicabilidade entre vários tipos de visualizações e produzir uma recomendação dos tipos de visualização mais aderentes no acompanhamento do progresso no aprendizado dos alunos.

1.1 Trabalhos relacionados

Forsell [6] discorre sobre a importância de um processo de pesquisa e construção de experimento de forma a evitar resultados ambíguos ou contaminados por más práticas na pesquisa sobre visualizações como erros nos tipos de participantes, condução de avaliações e maneira de reportar os resultados.

Fouh *et al.* [8] aborda várias ferramentas de visualização de algoritmos, comentando que pesquisas realizadas sobre a utilização de tais ferramentas concluíram que estas geram benefícios no processo de aprendizagem. Frisa ainda que ainda há muito espaço para pesquisa nas interações complexas entre programas de visualizações, alunos, ambientes de aprendizagem, formas de engajamento e objetivos particulares de aprendizado.

Em seus estudos, Moissa *et al.* [13] aborda as ferramentas de visualização *LeMo*, *WET* e *AdaptWeb*[3]. Conclui que ao demonstrar a trajetória de aprendizagem dos alunos os professores são capazes de melhorar seu entendimento com relação ao comportamento dos alunos e até mesmo identificar ou antecipar problemas nos processos de aprendizagem. O autor aborda diferentes formas de representação de trilhas de aprendizagem. Apesar de o artigo reconhecer a importância de tais representações, foi realizado apenas um estudo preliminar sobre as preferências de professores com relação às trilhas, que ficaram para serem incorporadas à ferramenta *AdaptWeb* futuramente.

Fields *et al.* [5] realiza um estudo sobre avaliação do aprendizado de jovens novatos em um ambiente de aprendizado baseado em projetos sem final definido (projetos onde os alunos não têm uma meta fixa e devem avançar os projetos tanto quanto possível). Através de análises na programação dentro do contexto social do aprendizado infantil o autor visava obter um melhor entendimento sobre suas trajetórias de programação. O estudo foi realizado com 64 crianças com idades de 10 a 13 anos e utilizou a ferramenta *Scratch 2.0*[4] a fim de achar padrões nos blocos de códigos utilizados pelos participantes com o objetivo de investigar os conceitos utilizados. O autor relata a importância dos testes qualitativos e quantitativos na análise dos dados obtidos, e chama atenção para fatores limitantes do estudo. Apesar de tratar de trajetórias de programação, que pode ser considerada uma trajetória de aprendizado, o artigo não explora diferentes formas de apresentar a mesma trajetória nem avalia o grau de comunicabilidade das visualizações.

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[3]http://adaptweb.sourceforge.net/
[4]https://scratch.mit.edu/download/scratch2

Utilizando-se de questionários e atividades de programação visual, Rose *et al.* [19] realiza um estudo com 158 alunos de um curso de ciência da informação e comunicação. Através de atividades de programação visual envolvendo um robô e cartas que ditam suas ações. Conclui que a programação visual pode ser muito importante para a evolução de múltiplas perspectivas de pensamento computacional. O artigo não trata da trajetória de aprendizado do aluno nem aborda a visualização desses resultados na forma de trilhas de aprendizagem.

Hammer & Sikorski [9] discorrem sobre progressões de aprendizado, desafiando a noção de que elas sejam apenas sequências generalizáveis. O trabalho chama a atenção para a coerência e agregação dos dados, afirmando que a coerência não é estática e que possíveis "outliers" nos dados podem conter dados valiosos que não devem ser descartados apenas por fugirem do padrão.

Já Tafner [22] trata das trilhas de aprendizagem e de sua importância no processo de ensino e consequentemente na construção do conhecimento. Utilizando-se de Ambientes Virtuais de Aprendizagem - AVA (entende-se por AVA os ambientes de aprendizagem que favorecem a construção do conhecimento [4]), disserta sobre as trilhas serem caminhos virtuais de aprendizagem capazes de promover e desenvolver competências no que concerne ao conhecimento, à habilidade, à atitude, à interação, interatividade e autonomia. De acordo com Tafner [22] a concepção de trilhas de aprendizado favorecem a otimização do desempenho e da utilização dos AVA. O autor concentra-se em uma avaliação geral da performance do novo AVA apresentado mas limita-se a esse escopo, não fazendo nenhuma análise ou comparações em relação a diferentes formas de visualização das trilhas de aprendizagem.

Na mesma linha, Fortenbacher *et al.* [7] utiliza-se da ferramenta *LeMo* para coletar dados de alunos em três diferentes plataformas (Moodle[5], Clix[6] e Chemgapedia[7]), destacando suas visualizações interativas como diferencial em relação a outras ferramentas.Apresenta visualizações com vários níveis de detalhes e vários tipos de gráficos como histogramas e grafos,analisando variáveis como tempo em atividade, performance, trilhas percorridas. Também trata de boas práticas com relação à privacidade dos alunos cujos dados estão sendo coletados e relata as capacidades da ferramenta protótipo *LeMo* de analisar os caminhos de aprendizado mais frequentes. O autor procura evidenciar as capacidades da ferramenta analisada, não abordando nem comparando diferentes visualizações sobre as trilhas de aprendizagem ou seu impacto ou

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[5]https://moodle.org/
[6]https://www.im-c.com/learning-technologies/learning-management/
[7]http://www.chemgapedia.de/vsengine/

4

aderência nos objetivos dos educadores.

A análise em trilhas de aprendizado também é realizada por Yang *et al.* [24], que faz através da ferramenta *Scratch*[8] medições de três aspectos principais no aprendizado de 3852 usuários: quantidade aprendida, velocidade do aprendizado e potencial de conhecimento prévio. Também é medido o aumento do vocabulário dos usuários. Através das trajetórias de aprendizado dos usuários, eles são divididos entre quatro grupos com padrões canônicos através do método de clusterização kmeans++. O artigo foca nas análises do desempenho dos alunos, mas carece de estudo sobre a aderência da apresentação dos dados aos professores na forma de trilhas de aprendizado.

Na linha de aprendizado adaptativo, Cai [2] apresenta uma avaliação da ferramenta *Intelipath* cuja função é criar uma trilha de aprendizado de acordo com o conhecimento possuído por cada aluno, ao mesmo tempo em que auxilia na avaliação e melhoria das disciplinas. As visualizações geradas pela ferramenta ficam disponíveis para professores e alunos, a fim de permitir que os alunos observem seu próprio progresso. O estudo resultou na conclusão que houve melhora na performance dos alunos em 15 dos 16 cursos onde a ferramenta foi aplicada.

A revisão sistemática da literatura com relação às trilhas de aprendizado feita por Ramos *et al.* [16] investigou como as trilhas de aprendizagem são apresentadas nos sistemas de e-learning e se as representações eram vistas por professores e alunos. Ramos *et al.* [16] conclui que a maioria das trilhas são representadas através de grafos (quando o aluno pode percorrer diversos caminhos no processo de aprendizado) e em seguida por sequenciamento (trilhas de aprendizagem lineares delimitando um único caminho a ser seguido).

Kuosa *et al.* [11] explora ferramentas que utilizam dados gravados de usuários a fim de gerar visualizações interativas, permitindo que alunos e professores analisem seu progresso nos cursos, incentivando assim um maior engajamento. Apesar de não tratar de trilhas de aprendizagem em si, discorre sobre a utilização das informações gravadas a fim de aumentar o engajamento dos alunos e auxiliar professores a entenderem o nível de aprendizado que os alunos atingiram.

Rich *et al.* [17] faz uma análise de diversos artigos sobre aprendizado de pensamento computacional. O autor define diversos objetivos de aprendizado e suas conexões de acordo com a literatura disponível, destacando 3 tipos de trajetória de aprendizado computacional: sequência, repetição e condicionais.

Na mesma linha de pesquisa em outro artigo, Rich *et al.* [18] apresenta uma trajetória

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[8]https://scratch.mit.edu/

de aprendizado para a decomposição em um contexto de pensamento computacional e ciência da computação. Através de 63 objetivos de aprendizado, posteriormente transformados em 13 objetivos de consenso, são feitas previsões, através de *frameworks* conceituais, sobre as trajetórias que os alunos podem seguir através desses objetivos de consenso. Para Rich *et al.* [18], a trajetória de aprendizado consiste em uma predição sobre um possível caminho de aprendizado. O artigo no entanto não apresenta nenhuma forma de avaliação visual sobre a efetividade das representações de tais trajetórias, fazendo apenas uma análise teórica utilizando a literatura disponível.

A literatura apresenta alguns artigos que tangem o uso de trilhas de aprendizado e até mesmo a forma como a elas são apresentadas [16]. No entanto há uma lacuna no sentido de avaliar quais seriam as formas de visualização de trilhas mais aderentes às necessidades dos professores.

2   Hipótese

Considerando que diferentes formas de visualizações de trilhas de aprendizagem podem ser utilizadas, a hipótese deste projeto é que existem visualizações que melhor atendem as necessidades de professores para analisar as trilhas de aprendizagem.

3   Objetivos

O objetivo deste projeto de pesquisa será realizar uma avaliação de visualizações que apresentem trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação. O público alvo destas visualizações será os professores do ensino básico. Ao final deste projeto, será proposto um conjunto de recomendações que auxiliem a criação de visualizações de trilhas de aprendizagem que sejam mais aderentes às necessidades dos professores.

Tendo em vista o objetivo geral da pesquisa, pode-se determinar que deseja-se avaliar a usabilidade das visualizações. Esta avaliação terá como público-alvo professores do ensino básico e alunos do graduação e de pós-graduação em Pedagogia.

É importante destacar que esta proposta de pesquisa não tem como objetivo encontrar a melhor visualização para as trilhas de aprendizagem e sim sugerir quais visualizações atingem uma melhor usabilidade de informações para os professores do estudo a ser realizado.

4   Metodologia

4.1   Tipo de Estudo

Este trabalho se caracteriza como estudo de usabilidade com o objetivo de realizar uma avaliação de visualizações que apresentem trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação. O público alvo destas visualizações será professores do ensino básico.

4.2   Local da Pesquisa

A pesquisa ocorrerá nas dependências da Universidade Federal de São Carlos, Campus Sorocaba.

4.3   Aspectos éticos da pesquisa

Atendendo ao rigor ético e científico o projeto de pesquisa será encaminhado ao Comitê de Ética em Pesquisa em Seres Humanos da Universidade Federal de São Carlos e após sua anuência será iniciada a coleta de dados, de acordo com as recomendações da Resolução 466/12 do Conselho Nacional de Saúde do Ministério de Saúde (BRASIL, 2012).

4.4   Participantes

Os participantes serão convidados através de redes sociais e e-mail que será enviado a professores do ensino básico de Sorocaba e região. Também serão convidados alunos de graduação e pós graduação em Pedagogia da Universidade Federal de São Carlos campus Sorocaba. A mensagem conterá um breve resumo da pesquisa: objetivos, local onde será realizado o estudo, tarefas a serem realizadas, tempo estimado, esclarecimentos sobre a participação e contato dos pesquisadores. O recrutamento ocorrerá durante um mês e pretende-se atingir no mínimo 10 participantes. Os critérios de inclusão dos sujeitos na pesquisa são: já ser professor da educação básica ou ser aluno de graduação ou pós graduação em pedagogia. Os dados dos participantes que por livre espontânea vontade não concluírem o estudo não serão considerados na análise.

4.5   Instrumentos de Coleta de Dados

A coleta de dados dar-se-á por meio dos seguintes instrumentos: Software de gravação das ações do usuário no ambiente das visualizações (alguns exemplos são Lookback[9], Inspectlet[10], Hotjar[11]), gravador de voz para gravar as falas durante o uso, folha de anotações para o observador. Serão utilizados também questionários de perfil[12] e de *feedback* da experiência do usuário[13] que deverão ser respondidos pelos participantes através de um link no google forms[14].

Será utilizado para a coleta de *feedback* da experiência do usuário o questionário Self-assessment Manekin - SAM[1].O questionário SAM é um método de avaliação que utiliza pictogramas e apresenta questões relacionais à qualidade afetiva de um sistema computacional. Por meio dele é possível identificar três dimensões: satisfação, motivação e sentimento de domínio de uma pessoa ao utilizar um sistema computacional. O campo da satisfação vai de uma representação de uma figura com expressão triste até uma representação de uma figura com expressão feliz. Tal campo visa demonstrar o quão feliz ou satisfeito o usuário está com o ambiente avaliado.O campo da motivação indica o quão motivado ou animado o usuário está com o sistema que lhe é apresentado. Nesse campo as figura vão de uma representação de uma pessoa dormindo até uma pessoa que parece estar muito ativa. O campo do domínio indica o controle que usuário considera ter da situação. Do lado esquerdo a figura pequena indica pouco domínio, enquanto a figura grande do lado direito indica uma alta sensação de domínio ou controle. Cada dimensão é representada por uma escala com valores de 1 a 9 e o usuário deve escolher aqueles que melhor representam suas emoções [1].Foi adicionado ao SAM duas questões abertas para permitir que o participante relate sua experiência.

Durante o teste de usabilidade será também utilizado o protocolo "Think Aloud" [3] que consiste em o usuário expor seus pensamentos em voz alta a medida em que explora as visualizações. Através da fala do usuário e seu comportamento ao explorar as visualizações e seu ambiente pode-se perceber as dificuldades, dúvidas ou intenções do usuário.

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[9]https://lookback.io
[10]https://www.inspectlet.com
[11]https://www.hotjar.com
[12]Apêndice D
[13]Apêndice C
[14]https://docs.google.com/forms

4.6 Procedimentos

O estudo de usabilidade será conduzido nas dependências da UFSCar de Sorocaba. Serão montadas três estações de estudo onde em cada uma delas haverá um computador e com o software de captura de imagens instalado. Serão realizadas sessões com três participantes de cada vez. Durante a sessão do teste serão realizados os seguintes procedimentos. Inicialmente, o objetivo do estudo será brevemente descrito, assim como as tarefas a serem realizadas, os riscos e o tempo estimado. Igualmente, será explicado para os voluntários que sua participação pode ser interrompida a qualquer momento sem qualquer prejuízo na sua relação com o pesquisador. Se houver aceite na participação, o voluntário será instruído a ler o Termo de Consentimento Livre e Esclarecido (TCLE), Apêndice A, e a Autorização de Captação de Imagem, Som e Nome, Apêndice B. Caso concorde, ambos deverão ser assinados, de forma que serão duas vias de cada documento, sendo uma para o participante e uma para o pesquisador. Em seguida, o participante responderá um questionário de informações pessoais em que serão coletados idade, sexo e grau de escolaridade. O experimento terá início com o participante recebendo a descrição por escrito de um cenário hipotético e das atividades a serem realizadas. O participante deverá avaliar as visualizações apresentadas expondo seus pensamentos à medida em que for realizando as atividades. As ações realizadas pelo participante do experimento serão gravadas no ambiente das visualizações, e sua voz também será gravada. O participante será observado e anotações poderão ser feitas em caráter complementar pelo pesquisador. Após as atividades, o participante deverá responder o questionário SAM e mais duas questões abertas.

Por fim, agradecer-se-á aos voluntários. As sessões terão no máximo a duração de 1 hora.

5 Métodos de análises dos dados

Os dados serão analisados através da análise qualitativa de vídeo e voz. O vídeo conterá a gravação da interação do participante que será complementado por suas falas capturadas através do uso do Think aloud. Na análise de vídeo será buscado por problemas de usabilidade como por exemplo dúvidas, barreiras que impediam a realização de alguma tarefa ou parte dela ou tempo excessivo para conclusão de uma tarefa.Na análise dos vídeos será utilizada a técnica de *Open Coding*[21]. O *Open Coding* relaciona códigos a partes de texto. Esses códigos recebem denominações que dão certo significado às partes de texto às quais se referem. Subsequentemente essas codificações são revisitadas e agrupadas à medida que vários padrões de

informação forem identificados. Por exemplo, o código *interface* poderia ser designado a partes do texto que trazem informações sobra a interface com o usuário. que consiste na criação de códigos que descrevam os problemas encontrados. Estes códigos representam etiquetas que serão relacionadas a trechos dos vídeos. Depois disto, será feita uma consolidação dos códigos para que enfim se descrevam os problemas encontrados comuns aos participantes.

O resultado do questionário SAM será analisado e serão construídos gráficos que demonstrem a distribuição dos dados. O resultado também será comparado com a análise qualitativa dos vídeos.

6 Riscos

Podem haver riscos de cansaço e estresse para os participantes. Esses riscos serão mitigados com sessões curtas (máximo de 1 hora) com um número reduzido de atividades por sessão.

7 Benefícios

O estudo usabilidade a ser realizado pode contribuir com a melhora na forma de apresentar dados educacionais para os professores. Por meio da análise dos resultados da usabilidade de cada visualização o estudo visa extrair boas práticas para construção de visualizações de trilhas de aprendizagem.

8 Desfecho Primário

É esperado após a realização do estudo que as impressões, opiniões e experiências de interação dos participantes, captadas através dos testes, permitam extrair boas práticas para construção de visualizações de trilhas de aprendizagem. As visualizações propostas serão refinadas a partir dos resultados do estudo.

9 Cronograma

A seguir são listadas as atividades previstas e seu tempo de execução pode ser visto na Tabela 1.

1. Criação de visualizações;

2. Planejamento do estudo de usabilidade

3. Recrutamento dos participantes

4. Preparação do ambiente de testes (computador e instalação de softwares)

5. Condução do estudo;

6. Análise dos dados coletados no estudo;

7. Extração de boas práticas;

8. Refinamento das visualizações de acordo com os resultados coletados.

Table 1: Cronograma das atividades em desenvolvimento (cinza escuro) e previstas (cinza claro).

Atividades	2019						2020		
	7	8	9	10	11	12	1	2	3
1	███	░	░						
2		░	░						
3			░						
4			░						
5				░	░				
6				░	░	░			
7					░	░			
8					░	░			

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APÊNDICE A - Termo de Consentimento Livre e Esclarecido (TCLE)

Você está sendo convidado para participar de uma pesquisa intitulada "Avaliação de visualizações de trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação". Temo-se como objetivo com essa pesquisa investigar a usabilidade de visualizações de trilhas de aprendizagem para o ensino do pensamento computacional.

Diante disso, solicitamos o seu consentimento para participação no estudo, em especial quanto a coleta de dados. Para decidir sobre o seu consentimento, é importante que você conheça as seguintes informações sobre a pesquisa:

- Os dados coletados durante o estudo destinam-se estritamente as atividades de cunho acadêmico;

- Os pesquisadores se comprometem em divulgar os resultados da pesquisa para toda a instituição, após a conclusão do trabalho. A divulgação desses resultados pauta-se no respeito à sua privacidade, e o anonimato dos participantes será preservado em quaisquer documentos que elaborarmos;

- O consentimento para qualquer atividade que envolva coleta de dados é uma escolha livre, feita mediante a prestação de todos os esclarecimentos necessários sobre a pesquisa;

- O consentimento para outras atividades de coleta de dados incluem também filmagem, fotos, áudios, ou qualquer outro meio necessário, capaz de contribuir para a análise da pesquisa;

- A transmissão e reprodução de produtos audiovisuais e/ou resultantes são de uso exclusivo para o desenvolvimento da pesquisa, ou seja, esses materiais não serão distribuídos para terceiros, em nenhuma hipótese, e serão usados apenas com intuito acadêmico;

- O seu não consentimento quanto à coleta de dados implica somente no não uso e não divulgação desses dados, uma vez que as atividades a serem respondidas e aplicadas no curso compõem parte da avaliação do mesmo.

- Qualquer dúvida quanto a elaboração desse estudo é possível contatar as pesquisadoras pelo e-mail jmichelfv@gmail.com.

Data da Assinatura:

Assinatura:

APÊNDICE B - Autorização de Captação de Imagem, Som e Nome

Nome do participante:

Declaro que entendi os objetivos, riscos e benefícios de minha participação na pesquisa. Sendo assim, assinalo uma das opções a seguir, esclarecendo que:

☐ Dou meu consentimento para a realização dos testes e atividades a serem efetuados ao longo do curso, assim como de qualquer outro meio de coleta de dados (como filmagens, imagens e áudios).

☐ Não dou meu consentimento para a realização dos testes e atividades a serem efetuados ao longo do curso, assim como de qualquer outro meio de coleta de dados (como filmagens, imagens e áudios)

Data da Assinatura:

Assinatura:

APÊNDICE C - Questionário de usabilidade - questionário SAM
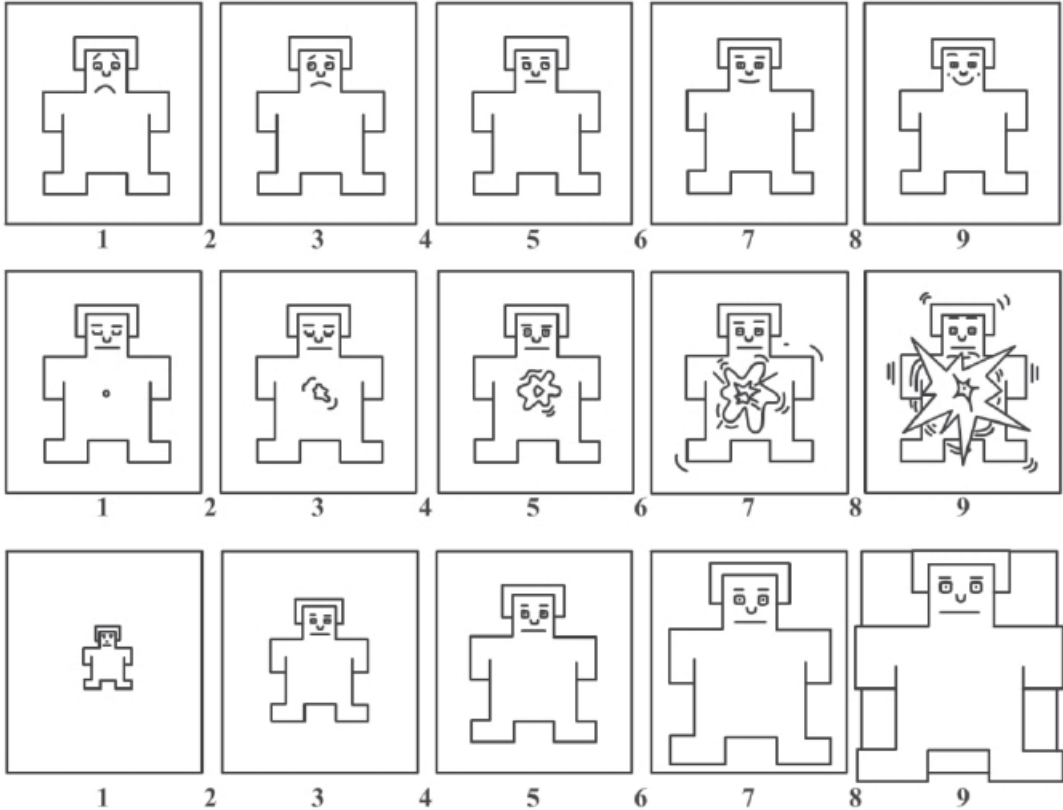
Figure 1: Questionário SAM
[20]

O que você mudaria nas visualizações?

Você tem algum comentário sobre as visualizações?

APÊNDICE D - Questionário de perfil

1 - Indique a qual faixa etária você se enquadra:

☐ Abaixo de 22 anos

☐ Entre 22 e 30 anos

☐ Entre 31 e 40 anos

☐ Entre 41 e 50 anos

☐ Acima de 50 anos

2 - Selecione o seu sexo:

☐ Masculino

☐ Feminino

☐ Prefiro não informar

3 - Indique qual o seu nível de formação acadêmica (caso você tenha diferentes formações é possível assinalar mais de uma resposta):

☐ Graduação em Pedagogia (Licenciatura)

☐ Pós-Graduação Stricto Sensu (Mestrado e/ou Doutorado) em Pedagogia

☐ Outro:

4 - Qual a sua frequência semanal de acesso à internet:

☐ não acesso a internet

☐ 1 a 4 vezes

☐ 5 a 8 vezes

☐ mais de 9 vezes

5 - Quais os dispositivos que você usa para acessar a internet? (marque todos os que você utiliza):

☐ smartfone

☐ computador

☐ tablet

☐ computador

☐ nenhum

5 - Você costuma usar quais dos aplicativos abaixo com fins educacionais?(marque todos os que você utilizar):

☐ Code

☐ Scratch

☐ Youtube

☐ Kan Academy

☐ Moodle

☐ outros:

6 - Onde você costuma usar esses aplicativos ou softwares?(marque todos os lugares em que você utilizar):

☐ casa

☐ escola

☐ casa de parentes

☐ universidade

☐ nenhum

☐ outros:

6 -Quais tipo de gráficos você costuma utilizar para analisar dados educacionais?(marque todos os que você utilizar):

☐ gráfico de pizza

☐ gráfico de áreas

☐ gráfico de linhas

☐ gráfico de diferenças

☐ gráfico de barras

☐ gráfico de rede

☐ grafos

☐ histograma

☐ boxplot

☐ infográficos

☐ diagramas

☐ gráficos de árvore

☐ nenhum

☐ outros:

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

(Resolução 466/2012 do CNS)

AVALIAÇÃO DE VISUALIZAÇÕES DE TRILHAS DE APRENDIZAGEM PARA O ENSINO DE PENSAMENTO COMPUTACIONAL COM FOCO EM PROGRAMAÇÃO

Eu, José Michel Fogaça Vieira, estudante do Programa de Pós-Graduação em Ciência da Computação da Universidade Federal de São Carlos – UFSCar o(a) convido a participar da pesquisa "Avaliação de visualizações de trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação" orientada pela Profª Drª Luciana Aparecida Martinez Zaina.

Devido à integração da computação no auxílio ao processo científico e ao desenvolvimento de outras ciências e sua importância crescente como ciência em si, o ensino computacional passou a ganhar mais importância nos programas curriculares de diversas escolas.

Este projeto de pesquisa objetiva avaliar diferentes tipos de visualizações de trajetórias de aprendizado relacionadas com aprendizado de pensamento computacional com foco em programação. Com a colaboração de professores do ensino básico e estudantes de pedagogia, o projeto visa obter uma classificação de usabilidade entre vários tipos de visualizações e produzir uma recomendação dos tipos de visualização mais aderentes no acompanhamento do progresso no aprendizado dos alunos.

Você foi selecionado (a) por ser profissional ou estudante na área de Pedagogia. Primeiramente você será convidado a responder alguns questionários sobre diversos aspectos

que envolvem seu contato com computadores e aparelhos eletrônicos semelhantes. Posteriormente será convidado a participar de uma sessão de um estudo experimental de usabilidade de uma ferramenta de visualização.

O estudo consistirá em um questionário de perfil (a ser respondido online) e um teste de usabilidade seguido de um questionário sobre as atividades propostas. O estudo com os participantes será realizado nas dependências da UFSCar- campus Sorocaba. Todos os encontros contarão com a participação de um relator, isento de vínculo com os participantes. As atividades e questões propostas não serão invasivas à intimidade ou integridade física ou mental dos participantes, entretanto, esclareço que a participação na pesquisa pode gerar estresse ou cansaço. Diante dessas situações, os participantes terão garantidas sessões curtas (menos de uma hora) e um número reduzido de atividades por sessão. Em caso de encerramento das entrevistas por qualquer fator descrito acima, o pesquisador irá orientá-lo e encaminhá-lo para profissionais especialistas e serviços disponíveis, se necessário, visando o bem-estar de todos os participantes.

Sua participação nessa pesquisa auxiliará na obtenção de dados que poderão ser utilizados para fins científicos, proporcionando maiores informações e discussões que poderão trazer benefícios para a área do Ensino Computacional na Educação, para a construção de novos conhecimentos e para a identificação de novas alternativas e possibilidades para o trabalho dos professores. O pesquisador realizará o acompanhamento de todos os procedimentos e atividades desenvolvidas durante o trabalho.

Sua participação é voluntária e não haverá compensação em dinheiro pela sua participação. A qualquer momento o (a) senhor (a) pode desistir de participar e retirar seu consentimento. Sua recusa ou desistência não lhe trará nenhum prejuízo profissional, seja em sua relação ao pesquisador, à Instituição em que trabalha ou à Universidade Federal de São Carlos.

Todas as informações obtidas através da pesquisa serão confidenciais, sendo assegurado o sigilo sobre sua participação em todas as etapas do estudo. Caso haja menção a nomes, a eles serão atribuídas letras, com garantia de anonimato nos resultados e publicações, impossibilitando sua identificação.

Solicito sua autorização para gravação em áudio das atividades a gravação das telas das atividades enquanto você as utiliza. As gravações realizadas durante as atividades serão posteriormente analisadas pelo pesquisador. A transmissão e reprodução de produtos audiovisuais e/ou resultantes são de uso exclusivo para o desenvolvimento da pesquisa, ou seja, esses materiais não serão distribuídos para terceiros, em nenhuma hipótese, e serão usados apenas com intuito acadêmico. Depois das atividades propostas, cada participante deverá responder um questionário de avaliação e usabilidade com relação às atividades propostas.

Se você tiver qualquer problema ou dúvida durante a sua participação na pesquisa poderá comunicar-se pelo telefone (015)98127-2168. Você receberá uma cópia deste termo onde consta o telefone e o endereço do pesquisador principal, podendo tirar suas dúvidas sobre o projeto e sua participação, agora ou a qualquer momento.

Declaro que entendi os objetivos, riscos e benefícios de minha participação na pesquisa e concordo em participar. O pesquisador me informou que o projeto foi aprovado pelo Comitê de Ética em Pesquisa em Seres Humanos da UFSCar que funciona na Pró-Reitoria de Pós-Graduação e Pesquisa da Universidade Federal de São Carlos, localizada na Rodovia Washington Luiz, Km. 235 - Caixa Postal 676 - CEP 13.565-905 - São Carlos - SP – Brasil. Fone (16) 3351-8110. Endereço eletrônico: cephumanos@ufscar.br

Endereço para contato (24 horas por dia e sete dias por semana):

Pesquisador Responsável: José Michel Fogaça Vieira

Endereço: Rua Manoel Lopes 33 – Sorocaba – São Paulo

Contato telefônico:15 981272168   e-mail: jmichelfv@gmail.com

Local e data: _____

_____   _____

Nome do Pesquisador   Assinatura do Pesquisador

_____   _____

Nome do Participante   Assinatura do Participante

Autorização de Captação de Imagem, Som e Nome

Nome do participante:

Declaro que entendi os objetivos, riscos e benefícios de minha participação na pesquisa. Sendo assim, assinalo uma das opções a seguir, esclarecendo que:

- ❏ Dou meu consentimento para a realização dos testes e atividades a serem efetuados ao longo do curso, assim como de qualquer outro meio de coleta de dados (como filmagens, imagens e áudios).

- ❏ Não dou meu consentimento para a realização dos testes e atividades a serem efetuados ao longo do curso, assim como de qualquer outro meio de coleta de dados (como filmagens, imagens e áudios)

Data da Assinatura:_____

Assinatura:_____

ANNEX A – Ethics commitee approval

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Avaliação de visualizações de trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação

Pesquisador: JOSE MICHEL FOGACA VIEIRA

Área Temática:

Versão: 2

CAAE: 18606019.2.0000.5504

Instituição Proponente: Departamento de Computação

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.750.430

Apresentação do Projeto:

O projeto é apresentado adequadamente.

Este trabalho se caracteriza como estudo de usabilidade com o objetivo de realizar uma avaliação de visualizações que apresentem trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação. O público alvo destas visualizações serão professores do ensino básico. Os participantes serão convidados através de redes sociais e e-mail que ser a enviado a professores do ensino básico de Sorocaba e região. Também serão convidados alunos de graduação e pós graduação em Pedagogia da Universidade Federal de São Carlos campus Sorocaba. A mensagem conterá um breve resumo da pesquisa: objetivos, local onde será realizado o estudo,

tarefas a serem realizadas, tempo estimado, esclarecimentos sobre a participação e contato dos pesquisadores. O recrutamento ocorrer a durante um mês e pretende-se atingir no mínimo 10 participantes. Os critérios de inclusão dos sujeitos na pesquisa são: já ser professor da educação básica ou ser aluno de graduação ou pás graduação em pedagogia. Os dados dos participantes que por livre espontânea vontade não concluírem o estudo não serão considerados na análise. O estudo de usabilidade será conduzido nas dependências da UFSCar de Sorocaba. Serão montadas três estações de estudo onde em cada uma delas haverá um computador e com o software de captura de imagens instalado. Serão realizadas sessões com três participantes de

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Bairro: JARDIM GUANABARA   **CEP:** 13.565-905
UF: SP   **Município:** SAO CARLOS
Telefone: (16)3351-9685   **E-mail:** cephumanos@ufscar.br

Página 01 de 04

cada vez. Durante a sessão do teste serão realizados os seguintes procedimentos. Inicialmente, o objetivo do estudo será brevemente descrito, assim como as tarefas a serem realizadas, os riscos e o tempo estimado. Igualmente, será explicado para os voluntários que sua participação pode ser interrompida a qualquer momento sem qualquer prejuízo na sua relação com o pesquisador. Se houver aceite na participação, o voluntario será instruído a ler o Termo de Consentimento Livre e Esclarecido (TCLE), e a Autorização de Captação de Imagem, Som e Nome. Caso concorde, ambos deverão ser assinados, de forma que serão duas vias de cada documento, sendo uma para o participante e uma para o pesquisador. Em seguida, o participante responder a um questionário de informações pessoais em que serão coletados idade, sexo e grau de escolaridade. O experimento terá início com o participante recebendo a descrição por escrito de um cenário hipotético e das atividades a serem realizadas. O participante deverá avaliar as visualizações apresentadas expondo seus pensamentos à medida em que for realizando as atividades. As ações realizadas pelo participante do experimento serão gravadas no ambiente das visualizações, e sua voz também será gravada. O participante será observado e anotações poderão ser feitas em caráter complementar pelo pesquisador. Após as atividades, o participante deverá responder o questionário SAM e mais duas questões abertas. Por fim, agradecer-se-á aos voluntários. As sessões terão no máximo a duração de 1 hora

Objetivo da Pesquisa:

Os objetivos da pesquisa são apresentados com clareza.

O objetivo deste projeto de pesquisa será realizar uma avaliação de visualizações que apresentem trilhas de aprendizagem para o ensino de pensamento computacional com foco em programação.

Avaliação dos Riscos e Benefícios:

Os riscos e benefícios são apresentados adequadamente no TCLE e resumo do projeto.

Riscos:

Podem haver riscos de cansaço e estresse para os participantes. Esses riscos serão mitigados com sessões curtas (máximo de 1 hora) com um

número reduzido de atividades por sessão.

Benefícios:

O estudo usabilidade a ser realizado pode contribuir com a melhora na forma de apresentar dados educacionais para os professores. Por meio da análise dos resultados da usabilidade de cada

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Telefone: (16)3351-9685   **E-mail:** cephumanos@ufscar.br

visualização o estudo visa extrair boas práticas para construção de visualizações de trilhas de aprendizagem.

Comentários e Considerações sobre a Pesquisa:

Pesquisa relevante.

Considerações sobre os Termos de apresentação obrigatória:

Todos os documentos obrigatórios são apresentados.

Conclusões ou Pendências e Lista de Inadequações:

As pendências apontadas anteriormente foram sanadas.Não há pendências.

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1404178.pdf	25/09/2019 08:54:28		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE_corrigido.pdf	25/09/2019 08:53:40	JOSE MICHEL FOGACA VIEIRA	Aceito
Projeto Detalhado / Brochura Investigador	Comite_de_etica.pdf	07/08/2019 13:56:24	JOSE MICHEL FOGACA VIEIRA	Aceito
Outros	Autorizacao_de_captacao_de_imagem_som_e_nome.pdf	07/08/2019 13:52:26	JOSE MICHEL FOGACA VIEIRA	Aceito
Outros	questionario_de_perfil.pdf	07/08/2019 13:51:30	JOSE MICHEL FOGACA VIEIRA	Aceito
Outros	questionario_de_usabilidade.pdf	07/08/2019 13:50:57	JOSE MICHEL FOGACA VIEIRA	Aceito
Folha de Rosto	folha_de_rosto.pdf	07/08/2019 13:48:18	JOSE MICHEL FOGACA VIEIRA	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

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Página 03 de 04

Continuação do Parecer: 3.750.430

SAO CARLOS, 07 de Dezembro de 2019

_____

Assinado por:
Priscilla Hortense
(Coordenador(a))