Building information visualization of e-learning data with Vis2Learning guidelines

Maylon Pires Macedo ⓘ [Federal University of São Carlos (UFSCar) | *macedomaylon@gmail.com*]
Ranilson Oscar Araújo Paiva ⓘ [Federal University of Alagoas (UFAL) | *ranilsonpaiva@ic.ufal.br*]
Isabela Gasparini ⓘ [Santa Catarina State University (UDESC) | *isabela.gasparini@udesc.br*]
Luciana A. M. Zaina ⓘ [Federal University of São Carlos (UFSCar) | *lzaina@ufscar.br*]

Abstract Information Visualization provides techniques to make better charts that enhance human perception about patterns in data and consequently support the user interpretation. In the educational area, visualizations help professionals to analyze a great amount of data to inform decisions to improve the learning-teaching process. The literature has shown that there is a gap in the development of educational data visualizations that fulfill end-user needs. This paper presents Vis2Learning: a scenario-based set of guidelines for the development of visualizations in the e-learning context. Vis2Learning provides a set of scenarios from which educational data visualizations can be developed, for each scenario, we provide the recommended chart, its aim, characteristics and examples of its application in the e-learning context. Besides, we provide a set of guidelines to improve users' interaction with each chart. We applied an online questionnaire with 34 end-users (Brazilian teachers), evaluating visualizations that were created by using the Vis2Learning. The results reveal: (1) the visualizations, based on Vis2Learning, were more suitable to be applied in the e-learning context; (2) some non-traditional visualization formats are difficult to interpret by users who did not have previous experience with visualizations in the e-learning context; and (3) experience in teaching is not strictly related to knowledge of charts about educational data.

1 Introduction

Information Visualization (InfoVis) area assists designers and developers in creating charts based on the needs of a target audience (Ware, 2012; Munzner, 2014). Based on Human-Computer Interaction (HCI) techniques, InfoVis aim is to support the development of charts to provide users with better graphics representation to enhance human perception of large amounts of data (Ware, 2012; Strey et al., 2018).

The visualization of data in flat tables does not help the user to infer patterns or find outliers by observing the data (Card et al., 1999). One of Infovis premises is the use of graphical representations to explore the abstraction promoted by the charts, which reduces the effort to obtain information based on the data (Carneiro and Mendonça, 2013).

The literature shows a growing interest in supporting the Education community with tools based on InfoVis, to allow the analysis of "educational data" and consequently to assist decision-making regarding the teaching-learning process (Reyes, 2015). According to the literature, educational data comprise information related to student's interactions with resources in the educational context, such as: activities; test score and demographic data (Jordão et al., 2014; Vieira et al., 2018; Tervakari et al., 2014).

Schwendimann et al. (2017) point to a gap in studies that explore the HCI in the context of visualizations about educational data. The authors point out that one of the challenges faced is the lack of investigations on techniques that help the development of graphic visualizations in order to fulfill the users' needs related to e-learning environments. E-learning environments are computer systems that can generate and store large amounts of data related to students' interaction with educational resources (Vieira et al., 2018).

We published a previous work entitled "*Vis2Learning: A scenario-based guide of recommendations for building educational data visualizations*" (Macedo et al., 2020) where we discuss details about the creation process, validation stages and evaluation of *Vis2Learning* by the lens of the visualization users. The *Vis2Learning* has 15 scenarios where, for each scenario, we provided: the recommended chart and its characteristics; application examples; and guidelines to enhance the user interaction with each chart. In this article, we present an extended version of Macedo et al. (2020). The novel contributions in this article are: (1) an expanded version of the analysis of the participants' profile; (2) a new correlation analysis between the participants' experience and the evaluation results; and (3) an expanded discussion about cases where the participants declared a low level of agreement about the charts created based on *Vis2Learning*.

The method used for creating *Vis2Learning* considered three stages. A first version was created (i) from a literature review, regarding visualizations created for e-learning systems. The first version was validated (ii) by three experts in the fields of Educational Data Mining (EDM), HCI and InfoVis, to generate a refined version. Two sets of charts were created, one of them based on the final version of *Vis2Learning* and the other did not apply the guidelines. These sets of charts were evaluated (iii) through a questionnaire that collected the perceptions of 34 end-users (e.g. teachers from Brazilian schools) in relation to the interpretation of the data presented by the charts.

The results of the evaluation suggest: (1) traditional visualizations, based on the guidelines, were perceived as the most appropriate for e-learning environments; and (2) more teaching experience is not correlated to knowledge about using visualizations. The contributions of this article are: (1)

to describe the systematic method applied in the creation of *Vis2Learning*; (2) to obtain and gather information, regarding the development of visualizations about educational data, which are the result of experiments with end-users; (3) to provide a scenario-based approach, which aids the developers (via guidelines) in understanding better ways to create a good information visualization for the e-learning context; and (4) to present the users' feedback about the visualizations created applying the *Vis2Learning*.

2 Background

In this section, we provide concepts about Information Visualization and present some related work.

2.1 Information Visualization Concepts

The InfoVis area aims to develop methods and techniques to enhance the interpretation of data based on the human perception. The main objective is to prevent users from employing excessive efforts on the stage of data preparation to dedicate more attention in the interpretation of data for decision making (Card et al., 1999). According to the InfoVis principles the developed visualization should amplify and allow the perception of emerging properties of the data, such as patterns, deviations, groupings and trends (Ware, 2012; Card and Jacko, 2012).

Munzner (2014) defines a framework to raise awareness about the importance of contextualizing the "idiom of visualization" to the user's data, tasks and domain during the design and evaluation of charts. Idiom of visualization can be perceived by visualization formats and features as zoom and pinch or data interaction features as navigation between different granularity of information.

A visual approach is recommended to prevent the user from using statistical techniques to analyze educational data, since these data are numerous and complex (Barbosa et al., 2017; Reyes, 2015). A poor definition of the visualization idiom can result in tools with low adherence to the target audience as the tool may not be useful for the user's task (Munzner, 2014). Tervakari et al. (2014) report that the visualizations that will be used by the target audience of e-learning systems need to be simple, direct and show relevant data without the need for the user to have statistical knowledge.

2.2 Related work

We found different processes in the literature for creating visualizations about educational data. Using prototypes Alves et al. (2018a) and Alves et al. (2018b) developed a process to drive the development of visualizations based on the context of use. To develop views for MOOCs Chen et al. (2016) propose an iterative process in which visualization prototypes are successively refined through interaction with users. At each stage of discussion and refinement, prototypes are gradually populated with data. With the same theme Ruipérez-Valiente et al. (2017) presents a process that uses analysis of the materials available in the learning environment and interviews with users to choose the visualization formats. Maldon-

ado et al. (2015) and Conde et al. (2015) proposed a workflow for the elaboration of visualizations whose data came from learning analytics (LA) algorithms.

Considering the construction of visualizations, Klerkx et al. (2017) proposes a set of guidelines to assist the creation of specific visualizations aimed at analyzing the learning path. The authors define a set of steps to determine the moment when the developer needs to define the necessary data and choose the visualization formats to fulfill the context needs.

Munzner's book (2014) has been a reference for the development of research in the field of visualization. However, the guidelines proposed by the author are abstract, as they do not deal with visualization formats aimed at a specific context and target audience. In addition, the guidelines are distributed throughout the different chapters of his book, requiring the complete reading of the work.

The related work above presents processes that apply HCI techniques to organize the creation of visualizations (Alves et al., 2018a,b; Chen et al., 2016; Ruipérez-Valiente et al., 2017; Maldonado et al., 2015; Conde et al., 2015; Klerkx et al., 2017). However, none of them deals effectively with the visualization formats that can be applied within the context of educational data in e-learning environments. Munzner (2014) presents aspects related to the idiom of the visualization disconnected from any context. The *Vis2Learning* differs at this point, it offers guidance on which visualization formats to use in each scenario of applicability in the e-learning context. In addition, the *Vis2Learning* provides information on how to work on the idiom of visualization to improve interaction in each recommended visualization format.

3 Method

The method used for creating *Vis2Learning* was divided into three stages, as shown in Figure 1.

We searched for articles with discussions about educational data visualizations created for e-learning systems. From the pertinent articles found, we extracted lessons learned, reported from the design and evaluation activities. The first version of *Vis2Learning* was created as a list of plain text containing hints to construct charts.

In the second stage, the first version of the *Vis2Learning* was validated individually by three experts in the fields of EDM, HCI and InfoVis. The experts gave a feedback based on their evaluation. This feedback was used to refine the guidelines, resulting in another version. This refined version was, again, validated by three experts, generating the final version, which is structured as guidelines, named *Vis2Learning*.

In the third stage, we continued evaluating *Vis2Learning*. The objective was to check if applying *Vis2Learning*, for creating visualizations, results in visualizations that are correctly interpreted by the target audience. A set of visualizations was created, where half of them applied the *Vis2Learning* guidelines, and the other half did not. The half that did not use the guidelines was created using the Google Sheets wizard for creating charts from a set of data. These
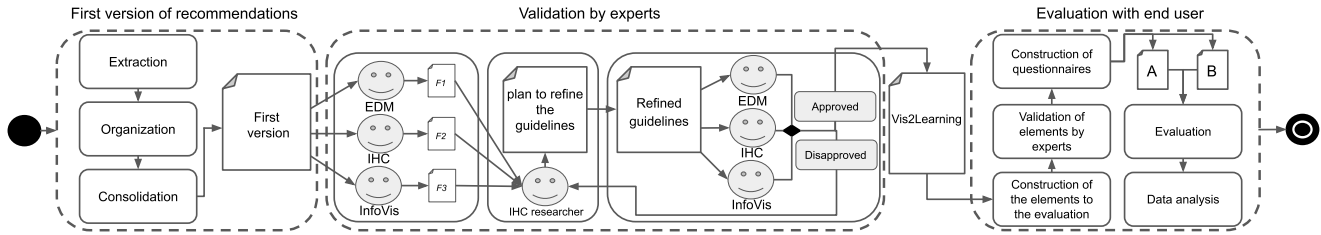
Figure 1. Method used to create, validate and evaluate the *Vis2Learning | Fn* represents the file with experts' feedback

visualizations were evaluated by 34 teachers, i.e. end-users, who worked at different school levels in Brazil. An online questionnaire was used to collect the participants' perception, regarding the interpretation of the information presented by the charts. The details of each stage are presented in the following sections.

4 Creating *Vis2Learning*

In this section, we present the first two stages of the *Vis2Learning* creation (see Figure 1).

4.1 The first version

The investigation of the literature for the elaboration of the first version, followed the protocol of a Systematic Literature Review (SLR) (Petersen et al., 2008). It is important to highlight that we did not perform a SLR, but we followed the same rigor to construct the search string. The objective was to find articles that describe the process used to design and/or develop visualizations of educational data for e-learning environments. The keywords of the search string were based on the previous reading of seminal articles with results that matched the creation of the guidelines.

After refining the search string (17 iterations, including and removing keywords), the final string was: *"("e-learning") AND ("Information Visualization" OR "Data visualization" OR "InfoVis" OR "Visual Analytics" OR "Learning Analytics" OR "Academic Analytics")"*. The search string was used in 5 scientific digital libraries: *ACM Digital Library*; *IEEE Explorer*; *Scopus*; *Science@Direct*; and the publications portal of the Brazilian Special Group on Informatics in Education (CEIE). We found 1207 articles [1].

We used these articles to create the guidelines, by following three steps: **extraction**; **organization**; and **consolidation**.

The **extraction** step was carried out by one of the researchers, from February to May 2019. First, the researcher read the title, abstract and results/conclusion of the 1207 articles, to search for lessons learned related to design and/or evaluation of visualizations about educational data. When an article reported lessons learned, it was tagged to be fully read in the next step. The tagged articles were fully read and all excerpts found were stored in a spreadsheet. To allow the

tracking of the excerpts, during the validation step, each excerpt received an identifier composed of "[ArticleNumber-ExcerptNumber]". For example, the first excerpt of the first article received the identifier [1-1]. In addition to the identifier, we included: the digital library name where the article was found, the page number of the article were the excerpt was found, the category in which the excerpt was inserted, the visualization format that the excerpt was related to, the excerpt taken from the article and a compilation of ideas elaborated by the authors based on the full article context.

We assigned categories to the excerpts with the aim of distinguishing the lessons learned types. The first category, called **data-based**, was assigned to excerpts that were related to some characteristic derived from the semantics of the data and were inherent to visualization. The **perception-based** category was used when the excerpt was related to the user's interpretation of the visualization format. Table 1 presents an example of an excerpt.

Table 1. Example of excerpt list

ID	Base	Pag	Category	Chart
12-2	Science@Direct	6	perception-based	area chart

Article
Improving the expressiveness of black-box models for predicting student's performance

Article excerpt
Progression charts can represent individual or group results. In the case of individual charts, it allows the detection of risk of failure of a student, and the effect of guiding. For instance, in Fig. 3, the student is classified as low or high performance in the first five weeks, with a low or medium level of confidence. However, the prediction of belonging to high performance class is dramatically reinforced from week 6, when the student reacts, so the performance results become much better in the last weeks. Another interesting use of progression chars is for studying group results (Fig. 4). In this case, the chart represents the average probability for every class and every week, considering all the students in a given group. The interpretation is similar to that of the individual charts, but in this case trends about the whole group can be detected. Besides the comparison between groups, it is very interesting comparing the progression of the whole group in accordance to the learning plan.

Recompilation of ideas
The area chart (called "progression" in excerpt) is ideal to represent the student's evolution over time. It can be used individually to provide feedback about students' pace and performance, allowing the student/teacher to realize the need to change the pace of studies. Also, it can be used to visualize how groups are performing against expectations and find patterns among everyone.

After performing the extraction step, the **organization** step was conducted in order to group the findings considering the visualization format and the category assigned to the excerpt. At this stage the excerpts were organized without removing or adding any information. This step also aimed to determine if there were similar or even duplicate excerpts, and then form a list of unique excerpts.

In the **consolidation** step, all excerpts referring to the same visualization format were recompiled and unified to generate the first version of the guideline. Each lesson learned was rewritten as a guideline, containing: identification code;

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chart name; the codes of the excerpts that were grouped; and a paragraph describing the guidelines. The guidelines were identified as guidelines *Gn* (17 in total), and general guidelines [2] *GGn* (9 in total). Table 2 presents an example of a guideline that was consolidated, in which the excerpts [1-5], [1-7] and [12-2] were brought together to generate guideline G6. Table 3 summarizes all the guidelines (G) and the general guidelines (GG), containing the visualization formats and the related excerpts.

Table 2. First version of guideline G6

Consolidation of excerpts about area charts	
ID	G6
Chart	area chart
Excerpts	[1-5], [1-7], [12-2]
guideline	The area chart is ideal for representing intermediate results and student progress, as it can represent the magnitude of change over time. Ideally the X axis should be the time, while the Y axis can state many variables representing measurements, for example the distribution of time spent on each question of an activity. This chart helps the student to be aware of their progress over time. When used individually to provide feedback, it allows the student/teacher to realize the need to change studies' approaches. It can also be used to visualize the performance of groups in relation to expectations and find patterns, which can represent difficulties of groups of students. When representing many variables, different colors and transparency can be useful to avoid losing information due to overlay.

Table 3. Overview of the first version

ID	Charts	Excerpts
G1	pie chart	[1-1], [7-4], [7-5], [8-1]
G2	bar chart	[1-2], [1-17], [1-16]
G3	boxplot	[2-3]
G4	violin plot	[2-4]
G5	radar chart	[1-3], [1-4]
G6	area chart	[1-5], [1-7], [12-2]
G7	line chart	[1-5], [1-6]
G8	parallel coordinates	[5-4]
G9	activity diagram	[1-11], [13-1]
G10	world cloud	[1-8], [10-1]
G11	map chart	[1-9]
G12	heat map	[12-1]
G13	treemaps	[4-1]
G14	dispersão	[1-10], [1-15], [5-1], [5-3]
G15	Q-Q plot	[2-5]
G16	hexbin plot	[5-2]
G17	bubble chart	[1-14]

ID	Excerpts
GG1	[1-12], [6-5]
GG2	[1-13], [6-2]
GG3	[2-1], [9-1]
GG4	[3-1], [6-4]
GG5	[6-1], [7-1]
GG6	[6-3]
GG7	[7-3]
GG8	[7-2]
GG9	[2-2]

4.2 First version Validation

The first version was validated by three experts in the fields of EDM, HCI and InfoVis. The three experts are senior researchers and will be named according to their field of expertise: EDM - EDM researcher and expert in building systems for recommending educational content based on data analysis; HCI - HCI researcher specialized in UX and information technology in education; and InfoVis - HCI researcher specialized in InfoVis, educational data and building systems for LA. The researchers were selected by specialty and convenience. The validation process was divided into three steps as described in the next paragraphs in this subsection.

In the first step, an electronic spreadsheet was prepared containing the first version of the guidelines and, for each guideline, the following were described: (i) the identification code; (ii) the name of the chart; (iii) an example image (which could be accessed by clicking on the name of the chart); (iv) the description of the guideline; (v) a column where the expert should deliberate his opinion (**A**pproved, **P**artially approved or **D**isapproved); (vi) a column for comments on the

content of the guideline (semantic); and (vii) a column for comments on problems related to the writing of the guideline (sintax).

The experts worked on their spreadsheet without accessing the spreadsheet of the others. In addition to filling out all columns with the feedback on each guideline (items from v to vii), all experts have also created generic fields to input comments on the structure and organization of the guidelines.

The second step was conducted after the experts' first review. The experts' generated a list, containing 71 related comments on the adjustments that should be applied to the guidelines. All notes made by the experts were complementary, with no conflicting or even redundant comments. The validation scores are presented in Table 4. All experts suggested that the format of presentation of the guidelines (in paragraphs) was suppressing important details of the excerpts. The format was changed in the final version.

Table 4. Score of guidelines in the first step of the validations by the experts

#	Disapproved	Partially approved	Approved
G1	0	2	1
G2	0	3	0
G3	1	2	0
G4	0	2	1
G5	0	2	1
G6	0	0	3
G7	0	2	1
G8	1	2	0
G9	0	2	1
G10	0	1	2
G11	0	1	2
G12	0	3	0
G13	0	2	1
G14	0	2	1
G15	0	1	2
G16	0	2	1
G17	0	2	1
GG1	0	1	2
GG2	0	3	0
GG3	0	2	1
GG4	0	1	2
GG5	1	0	2
GG6	0	2	1
GG7	1	1	1
GG8	0	2	1
GG9	1	2	0

The third step started with the definition of a new format for presenting the guidelines. In addition to the new presentation format, seven of the guidelines (G and GG) were excluded for presenting ill-defined contributions or for not making it clear the applicability for the area of visualization about educational data in e-learning environments (i.e. G3, G7, G8, GG2, GG5, GG7, GG9). The general guidelines received the questioning in relation to which visualization formats they could be applied to, so it was decided to remove the "General guidelines" classification and contextualize the content of these guidelines for each proposed visualization format. At the end of the third step the guidelines were transformed into a set of guidelines based on scenarios of applicability of visualizations about educational data in e-learning environments. The guideline was validated again by the experts and approved without further adjustments, generating the final version of the proposal called *Vis2Learning*.

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[2] Identification attributed to guidelines that could be applied in more than one visualization format covered by the first version of the guideline.

5 *Vis2Learning* guidelines

We defined a template to the writing of the guidelines final version. The template did not impose any limitation on the amount of information described in it. This avoided specific details, taken from the literature, to be out of our guideline specification. When a visualization does not have guidelines for a particular element, it is kept blank. Elements that should not be used, as they do not represent good practice, are filled with the label "normally not applied". The fact that an element is blank does not mean that there are no guidelines, but that during the search there were no experiences that could contribute to that approach.

Vis2Learning provides guidelines to support developers in the creation of visualizations that will be used by teachers, which means that teachers are the target audience. During the literature search, we run a string that did not include any keyword regarding "teachers". However, the literature review showed that the lessons learned, found in the papers, put teachers as the main end-users of the visualizations.

The final version of *Vis2Learning* contains 15 scenarios of application for visualizations about educational data in the context of e-learning. Each scenario has an identifier (SC) and is composed of the following elements: chart name; representation purpose; chart characteristics; application example; and guidelines. This last element has four subtopics related to the idiom of the proposed visualization for that scenario, which are: exact value; filtering data mechanisms; highlight data; and some particularities of that scenario.

In the first version of the guide, there were general guidelines that dealt with different aspects of the visualizations (colors, shapes and/or sizes) and were not specific to just one type of visualization. However, due to the relevance of these guidelines, they were incorporated for each visualization format and stored in the subtopics of the element called "guidelines".

The *Vis2Learning* has a total of 59 guidelines distributed among 15 scenarios of applicability for different formats of visualizations. For each visualization format there is a characterization field that was extracted from the literature on the types of data that it can represent. In addition, the guideline describes 24 examples for application of formats within e-learning systems. Table 5 presents scenario SC6. The full version of *Vis2Learning* is available at the link[3]. Table 6 presents a summary of the application scenarios in relation to the visualization formats contemplated.

6 Evaluation with end-users

This evaluation proposal was to collect the participants' perception about the charts that were created using *Vis2Learning*. Data was collected using an online questionnaire (Lazar et al., 2017). This evaluation followed the approval procedures of the Human Research Ethics Committee of UFSCar and was authorized by protocol number 31252720.1.0000.5504.

Table 5. Scenario 6 of *Vis2Learning*

Identification	
ID	SC6
Chart name	Area chart
Purpose	Illustrates the midway students' outcomes, showing the evolving and data changes over time
Aim	represents variables, associating them to progress viewing (e.g. percentage completed, time elapsed)
Chart characteristics	a continuous line passes through all the crossing points presented between the X and Y-axis
	it is recommended that the X-axis contains the progress scale (e.g. time, steps.), and that the Y-axis contains the quantitative variable
	the use of several lines is suitable to describe different groups of data
Example of application	provide students with a visualization of the distribution of time that they spent on each part/step of an activity
	from this visualization the students are able to evaluate their study pace and consequently make adjustments if they need
	it is also possible to visualize the performance of workgroups versus an expected outcome to search for difficulties that they could have in one activity
Guidelines	
Exact value	display the real values on tooltips when users hover the mouse on the chart
Filtering data mechanisms	provide ways to see the data of particular students
Highlight data	in cases of multiple variables representation, colors with transparency are recommended to avoid missing information caused by the overlapping of areas, for instance
Specificities	use patterns (e.g. dots, dashes) to contrast the areas in cases colors are not available; the 3D bar format is not recommended because it can insert difficulties to the comparison of data; provide the meaning of the colors and the format of the lines in captions

Table 6. Summarization of *Vis2Learning*

| ID	Purpose	Chart name
SC1	Distribution of student data in pre-planned categories	Pie chart
SC2	Representation of the total amount of data for a category	Horizontal bar chart
SC3	Compare values, or compare a value with an average or target value	Vertical bar chart
SC4	Quick identification of subgroups from the distribution of data	Violin plot
SC5	Illustrating data of different students' interactions with an educational resource	Radar chart
SC6	Illustrates the midway students' outcomes showing the evolution and changes in data over time	Area chart
SC7	Represents the instructional design of courses or steps of workgroup projects	Activity network diagram
SC8	Illustrates the most used terms used in courses or in forum discussions	Word cloud chart
SC9	Represents data from the geographic location of students	Map chart
SC10	Illustrates the performance of large groups of students	Heatmap chart
SC11	Shows the data about the students' participation, categorized by topics and ordered by a raking	Treemap chart
SC12	Shows a comparison of datasets (e.g. students' grades) to illustrate the cause-effect from the application of a teaching-learning method	Scatter plot
SC13	Compares a group of students' performance with baseline values	Q-Q plot
SC14	Compares datasets with a large volume (high density) of data to find out patterns	Hexbin plot
SC15	Provides an overview involving 3 variables (X, Y and Z) where X and Y are categories and Z is a quantitative number	Bubble chart

6.1 Planning

For evaluation, we created 15 examples of use (EU) of charts: one EU for each scenario (SC) in the guidelines. To question the participant about the interpretation of the information contained in the chart, for each EU there was an assertion. In order to carry out a comparative assessment, for each EU, two distinct charts were created. One of the charts was built following the guidelines of *Vis2Learning*, henceforth called Vis2LChart. The other chart was created using the Google Sheets wizard that generates a visualization from a data set, henceforth called GSheetChart. We decided to create these two charts to analyze if the target audience will have a different interpretation of the charts created using *Vis2Learning* and the other created using a generic approach that does not consider the context of use.

All these elements (EU, charts and statement) were validated by the three experts who validated the *Vis2Learning* (see Section 4.2). Figure 2 presents an example of all elements created regarding EU-4. First, each expert, individu-

EU-4: A teacher needs visualize the grades of students to observe in the group of fail students who can and who cannot retake the exam. For this, the teacher defined two passing scores.

Vis2LChart   **GSheetChart**
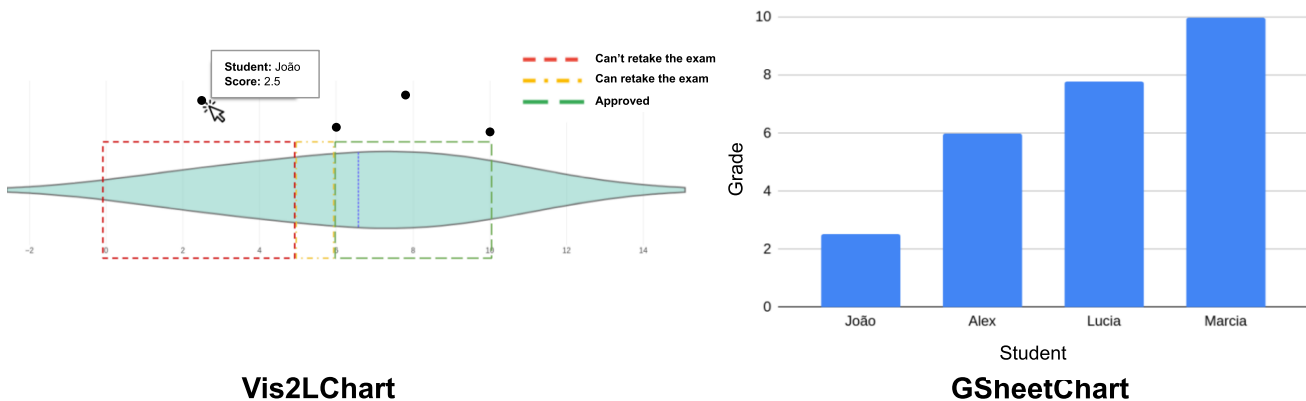
Statement: It is possible to clearly observe the students: approved, fail and fail with possibility to retake the exam ?

Figure 2. Elements built to EU-4

ally, analyzed and commented on all the elements created for the evaluation. These comments were compiled in a report. This report was presented to the three experts in an online meeting, where they had to accept the EU and their respective elements or suggest changes.

After performing the refinement of the elements created for the evaluation, two questionnaires were developed. The two questionnaires (A and B) contained the same EU and the same statements. However, the charts were distributed between the two questionnaires (A and B) alternately, so that both had Vis2LCharts and the GSheetCharts at random. For example, for questionnaire A and EU-1 a GSheetChart was presented, and for the EU-1 in questionnaire B the Vis2LChart was presented.

In the questionnaire, the EU, and its respective chart, were presented to the participants who should select their level of acceptance in accordance to the statement related to them. The degree of acceptance could be indicated using a 4-point Likert scale: I totally disagree; I partially disagree; I partially agree; and I totally agree. Johns (2005) and Garland (1991) point out that a small scale without a central point (neutral, I neither disagree nor agree or I don't know) takes the advantage of getting a more precise response from the participants. Johns (2005) argues that the neutral point is commonly used by the participants to avoid a possible conflict of opinion with the researcher. Thus, in our questionnaire, the 4-point scale was chosen.

The questionnaires A and B had 4 sections: (1) a welcome message and a brief explanation of the research aim; (2) the Informed Consent Form (ICF) explaining the research conditions and gathering the participant's acceptance (if the participant did not accept the ICF, the questionnaire was ended with a thank you message); (3) a demographic gathering about the participant's profile and their level of academic and professional experience; and finally, (4) the 15 EU to collect the par-

ticipants' perception about data presented by visualizations.

6.2 Execution and Analysis

The participants were invited via e-mail. To control access to the questionnaire, we designed an algorithm to calculate, in an ordinal way, the number of access and redirect the participant to questionnaire A if it was a even access number and if not, redirect the participant to questionnaire B. We adopted this strategy to balance the number of responses in each questionnaire and to prevent a participant from answering both questionnaires. We registered 123 accesses during the period the questionnaire was open. There were 34 questionnaire answers, being 17 for questionnaire A and 17 for questionnaire B.

We analyzed all the data collected, i.e. all the responses from questionnaire A and B. By joining all the data, we could have an overview of the evaluation [4]. Descriptive and inferential statistics Lazar et al. (2017) were used to explore the data from different lenses. The boxplot was used to observe medians and outliers of the participants' perceptions. To analyze whether the acceptance rates on the visualizations were influenced by the profile of the participants, the Fisher (1922) exact test was adopted. The details of the results are described in the following section.

6.3 Results

The results obtained through the analysis are presented in the next subsections in three perspectives: profile of the participants, perception of the participants about the charts and influence of the experience of the participants on their perception about the charts.

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[4] Raw data is available at: https://docs.google.com/spreadsheets/d/1LH4e3n33HpeSVP4kIRq0GeQu4sjBLSuCDQJBds8xTFo

6.3.1 Participants' profile

Regarding the 34 participants, 44% were above 41 years old and the most common level of education was post-graduate with about 30%, followed by the master's degree with approximately 24%. The levels of education in which the participants work are varied, however, higher education (38.2%) and middle school (20.6%) stand out as the main activities. Four participants stated that they were not acting as teachers, however, this answer reflects only the current moment of the participant since when analyzing the experience time teaching it is noted that the majority of participants (58.8%) had more than 6 years of experience. Only one participant, who was a student of pedagogy, had no professional experience in teaching.

All information collected from participants is presented in Table 7, each participant is identified with an ID (Pn). The table comprises information about: Identification - ID, age and the level of instruction; Job context - the graduate level that the participant work and time of experience; Knowledge - The level of knowledge informed by the participant about software development, InfoVis area, interactive charts and educational systems with data visualization about educational data; Use of charts - the participant preferences about use of charts in their job and personal use.

Participants were asked about experience on topics related to visualizations. Most of the participants had theoretical and/or practical knowledge about computer programming and the creation of interactive charts (See Figure 3 A and B). However, when asked about knowledge in the InfoVis area, only two participants declared deep knowledge (See Figure 3 C). Regarding the use of visualizations in the work environment, most of the participants declared they use it as their option and because it was necessary. The result of the question about the knowledge in educational systems with data visualization about educational data shows that more than half of the participants (67.6%) never used systems of this type (See Figure 3 D).
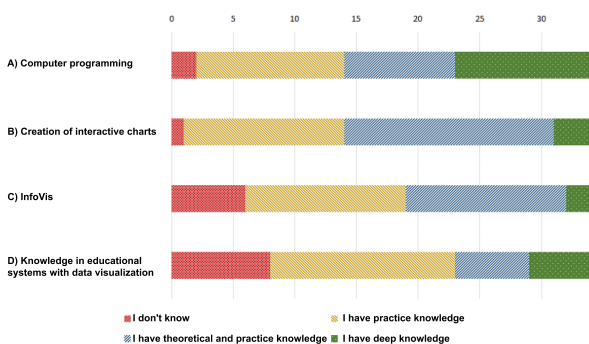

Figure 3. Participants profile

An open and non-mandatory question asked which systems the participants used to generate graphs. Each participant could list more than one system or none. There were 32 answers, and the most frequent answer was the use of spreadsheets (16 citations) and only 3 participants mentioned systems for educational context with the use of charts.

6.3.2 Participants perception about visualizations

Figure 4 presents an overview of the participants' perception about the visualizations related to the Vis2LCharts and the GSheetCharts. The participants expressed agreement in relation to the statements associated with the Vis2LChart and disagreed when the associated chart was GSheetChart. However, the median of the two groups pointed to the answer "I partially agree". The median found suggests that the participants showed a tendency to consider the interpretation using the GSheetCharts as partially adequate.
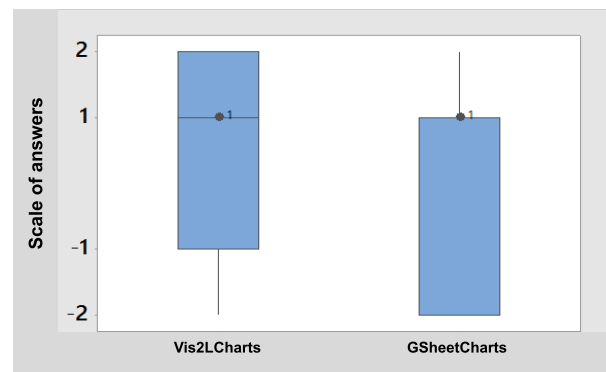

Figure 4. Comparison of perception of Vis2LCharts and GSheetCharts | Totally disagree (-2), Partially disagree (-1), Partially agree (1) e Totally agree (2)

A panel of boxplots, containing one chart for each scenario, was created to examine in depth the data that make up the median (Figure 5). In order to create Figure 5, data from the participants who interacted with GSheetCharts were normalized through the inversion of their semantic value. That is, the answers "I disagree" were replaced by "I agree" and so on.
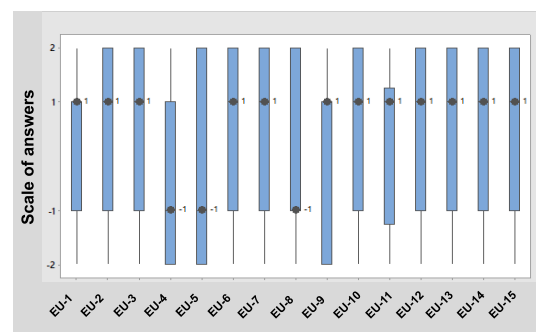

Figure 5. Distribution of answers by example of use (EU) | Legend: Totally disagree (-2), Partially disagree (-1), Partially agree (1) e Totally agree (2)

After the normalization, we aggregated the responses of all participants. Normalizing the data, we avoid the boxplots extend across the entire range of responses, which avoids hiding the outliers. The boxplots located between the middle and the top in Figure 5, as in the case of EU-2, EU-3, EU-6, EU-7, EU-8, EU-10, EU-12, EU-13, EU-14 and EU-15, represent scenarios where the Vis2LCharts was considered suitable for the context of e-learning, while the GSheetCharts received a lower agreement level.

Table 7. Participants profile | *** ESwDT**: educational systems with data visualization about educational data | **Knowledge**: (1) I've never heard of; (2) I have theoretical knowledge; (3) I have practical and theoretical knowledge; (4) I have deep knowledge | **Use of charts**: (1) I don't use it; (2) I used it a few times; (3) I always use it because it is necessary; (4) I always use

Identification			Job context		Knowledge				Use of charts	
#	Age	Instruction	Level	Experience	Develop	InfoVis	Charts	ESwDT*	Personal use	In job
P1	39	PhD	Technical	> 6 years	4	3	3	4	4	4
P2	47	M.Sc	Undergraduate degree	> 6 years	3	3	3	4	3	3
P3	20	Incomplete graduate	Middle school	< 1 year	3	2	2	1	1	2
P4	59	MBA	Elementary school	> 6 years	2	2	2	2	2	1
P5	23	Graduate	High school	< 1 year	2	1	2	1	1	1
P6	47	Graduate	Elementary school	> 6 years	2	2	2	2	1	1
P7	49	PhD	Undergraduate degree	> 6 years	3	3	2	2	2	2
P8	34	MBA	Middle school	> 6 years	2	1	2	2	1	1
P9	41	M.Sc	Elementary school	> 6 years	2	2	3	3	3	2
P10	38	MBA	Undergraduate degree	> 6 years	4	3	3	1	3	3
P11	32	MBA	Undergraduate degree	4 to 6 years	4	2	3	2	4	3
P12	26	M.Sc	Unemployed	4 to 6 years	3	2	3	2	3	1
P13	33	PhD	Undergraduate degree	4 to 6 years	1	1	1	1	1	1
P14	45	M.Sc	Undergraduate degree	> 6 years	4	4	4	4	4	4
P15	27	MBA	Elementary school	< 1 year	3	3	3	3	2	4
P16	35	Graduate	Undergraduate degree	4 to 6 years	2	2	2	2	2	1
P17	53	PhD	Undergraduate degree	> 6 years	2	3	3	2	2	3
P18	45	MBA	Technical	> 6 years	4	3	3	3	3	3
P19	28	MBA	Undergraduate degree	4 to 6 years	4	3	3	2	2	3
P20	22	M.Sc	Middle school	1 to 3 years	4	4	4	4	3	3
P21	24	MBA	Unemployed	1 to 3 years	4	3	3	3	4	2
P22	46	M.Sc	Undergraduate degree	> 6 years	4	2	2	2	2	2
P23	49	MBA	Elementary school	> 6 years	2	2	2	1	2	3
P24	36	MBA	Elementary school	> 6 years	1	1	3	1	1	3
P25	42	MBA	Elementary school	> 6 years	2	1	2	1	2	1
P26	44	M.Sc	Technical	> 6 years	3	3	3	3	3	3
P27	46	MBA	Undergraduate degree	4 to 6 years	2	2	2	2	2	2
P28	30	MBA	High school	< 1 year	3	3	3	3	3	3
P29	35	MBA	Technical	> 6 years	4	3	3	2	4	4
P30	23	Incomplete graduate	Unemployed	0 year	2	2	2	2	2	1
P31	26	Incomplete graduate	High school	> 6 years	2	3	3	4	2	3
P32	41	PhD	Undergraduate degree	> 6 years	4	2	3	2	2	3
P33	32	PhD	Undergraduate degree	4 to 6 years	3	1	4	1	2	2
P34	46	M.Sc	Unemployed	> 6 years	3	2	2	2	2	2

6.3.3 Influence of the participants' experience on the perception of the visualizations

The data collected in the evaluation were also analyzed by crossing the profile of the participants' perceptions about the Vis2LCharts. We verified if the participants' previous experience with visualizations systems about educational data could influence the choices they made for each EU. To conduct this verification, the Fisher (1922) exact test was performed. We chose this test because it was suitable to compare categorical data, collected from small samples (i.e. <1000). Besides that, it calculates the exact significance of the deviation from a null hypothesis using *p-value*, while other methods use an approximation. In addition to providing greater accuracy in small samples, the exact tests do not require a balanced or well-distributed sample (Mehta and Patel, 1996). Because it is a small sample (34 participants), a 95% (0.05) confidence interval was adopted to mitigate errors in the results[5]. The hypotheses formulated were:

- H0 - *The previous experience of the participant on visualizations in educational systems has no influence in the acceptance of Vis2LCharts*;
- H1 - *The previous experience of the participant on visualizations in educational systems has influence in the acceptance of Vis2LCharts*.

Table 8 shows the data used for this test. The *p-value* was *0.0392*, below the confidence interval (0.03 < 0.05). Considering this result, there is enough statistical significance to reject the null hypothesis. Thus, we can infer that the experience of the participants with educational systems with data

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visualization influenced the positive perception in relation to the Vis2LCharts.

Table 8. Previous experience on educational systems with visualizations vs feedback of Vis2LCharts

	Totally disagree	Partially disagree	Partially agree	Totally agree
Without experience	26	27	54	65
With experience	8	25	27	23

We also decided to check whether the participants' experience in teaching has influence in the acceptance of Vis2LCharts or not. In the participant's profile section of the questionnaire, the highest possible option for the participants' experience is "more than 6 years", for this analysis, we considered the participants that chose this option. The hypotheses formulated were:

- H0 - *The large experience in teaching (i.e. more than 6 years) has no influence in the acceptance of Vis2LCharts*;
- H1 - *The large experience in teaching (i.e. more than 6 years) has influence in the acceptance of Vis2LCharts*.

Table 9 shows the data used for this test. The *p-value* was *0.3270*, above the confidence interval. We can conclude that there is not enough statistical significance to reject the null hypothesis. Thus, we can observe that more experience in teaching does not, necessarily, ensure knowledge about the use of visualizations to gather information. This result reinforces the need to make the users aware about the possible uses and aims of each visualization format.

Table 9. Previous experience in teaching vs feedback of Vis2LCharts

	Totally disagree	Partially disagree	Partially agree	Totally agree
Less than 6 years	14	22	39	30
More than 6 years	20	30	42	58

7 Discussion

Related work (see Section 2.2) shows that most of the visualization proposals are focused on processes to organize the development of visualizations for e-learning systems (Alves et al., 2018a,b; Chen et al., 2016; Ruipérez-Valiente et al., 2017; Maldonado et al., 2015; Conde et al., 2015; Klerkx et al., 2017). Even though it is in the context of e-learning, none of these works provided guidelines of suitable formats of visualization for the e-learning field.

In the related work, the authors suggest that the developers search the literature for appropriate chart formats (Maldonado et al., 2015; Conde et al., 2015; Klerkx et al., 2017; Ruipérez-Valiente et al., 2017). *Vis2Learning* proposes a pragmatic way to assist developers in choosing the visualization format for e-learning systems, based on data and guided by application scenarios. None of the related work applied a systematic way to explore and organize the lessons learned about the use of visualizations, regarding educational data to support future implementations and that makes *Vis2Learning* different from these works.

7.1 Results of the study

Looking at Figure 5, we see cases that participants declared that both options are suitable for e-learning context (e.g. EU-1 and EU-11), cases that participants selected Vis2LCharts as suitable (e.g. EU-2, EU-3, EU-6, EU-7, EU-8, EU-10, EU-12, EU-13, EU-14 and EU-15) and cases that the participants selected the GSheetCharts (e.g. EU-4, EU-5 and EU-9).

Considering the formats used by GSheetCharts, we see the use of pie chart in EU-1 and bar chart in EU-11. Vieira et al. (2018) states that pie and bar charts are considered traditional and well accepted by teachers in educational context. In Paiva et al. (2019)'s survey, teachers pointed out that visualizations with non-traditional charts are useful but they stated they were more confident when using a traditional chart.

The visualization formats proposed for Vis2LCharts that received the lowest agreement level were: violin plot (EU-4); radar chart (EU-5); and activity diagram (EU-7). All the visualization formats mentioned are considered as non-traditional and their use, in the educational data visualization context, is relatively new (Vieira et al., 2018; Dourado et al., 2018).

In EU-4 case (See Figure 2) we see a non-traditional format used as Vis2LChart, called violin plot. As recommended by *Vis2Learning* and discussed by Barros et al. (2017), the violin plot is a suitable format for visualizing the distribution of data that have more than one group in its composition (e.g. students who passed and failed). This format is suitable for this EU, because it describes a case of a teacher that needs to visualize the distribution of students' grades in relation to

passing scores. Despite that, participants show a low level of agreement for Vis2LChart and this finding confirms the results reported by Paiva et al. (2019).

In EU-5 case the participants declared a low level of agreement for both visualizations. The GSheetChart, which was a line chart, received more positive answers in relation to the Vis2LChart which was a radar chart. The low level of agreement related to the Vis2LChart may have happened due to the lack of familiarity, from the audience, of this chart format. Dourado et al. (2018) stated that the radar chart is not among the most used in educational data visualization systems, while the line chart is widely used.

In EU-9 case (see Figure 6) the participants show a positive level of agreement for both charts presented. Vieira et al. (2018) conclude that the dot chart presented as GSheetChart (see Figure 6 B) is one of the three most traditional visualizations used in systems with visualization about educational data. Similar to the EU-5 case, familiarity with the chart presented as a GSheetChart may have affected the participants' level of agreement.

The majority of the participants declared to have more than 6 years of experience in teaching and our analysis showed that this experience is not directly related to knowledge about the use of visualizations to explore educational data. We pointed out that this experience does not contribute to overcome the cold start barrier about non-traditional charts.

Our analysis showed that the experience of the participants with educational systems that contain data visualizations, positively influenced the participants' perceptions, regarding Vis2LCharts. Vis2LCharts were created based on *Vis2Learning* and includes traditional and non-traditional visualization formats.

We conclude that when proposing a visualization, in addition to ensuring that it is appropriate to the user's context, it is important to provide the user with some information about the visualization format. A solution would be to provide a brief explanation and examples of what is the aim of the visualization format used.

7.2 Comparison with Munzner

Munzner (2014) is the most well-known reference on guidelines for information visualizations. However, the author's work provides the guidelines without setting them into a field or context. Being our proposal focused on the context of use, we decided to compare the *Vis2Learning* with the guidelines from Munzner's book.

To conduct the comparison, we followed some steps. First, we read the chapters of the Munzner's book and extracted the "rules of thumb"[6]. Munzner's rules of thumb were compared with the content presented in *Vis2Learning* by searching the linking between the guidelines. We consider that the two proposals have a linking when the *Vis2Learning* guidelines encompassed at least one of the rules of thumb.

We also created a categorization to classify the linking strength between the guidelines of both proposals. A category was assigned to the relationship when a guideline from *Vis2Learning*: **SP** - had the same purpose as a rule of thumb;

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[6]Term used by Munzner (2014) to identify the guidelines she proposed.
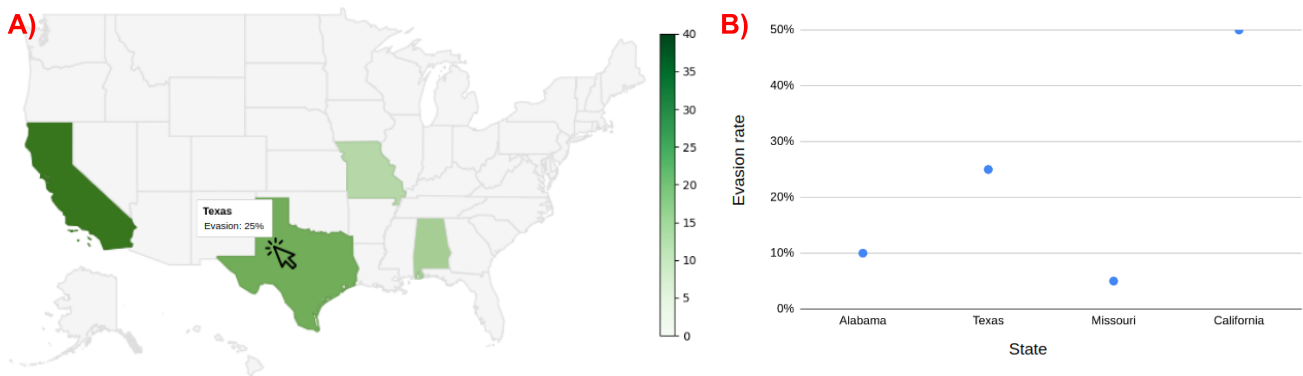
Figure 6. Charts presented on EU-9 in both questionnaires | A) is a Vis2LChart | B) is a GSheetChart
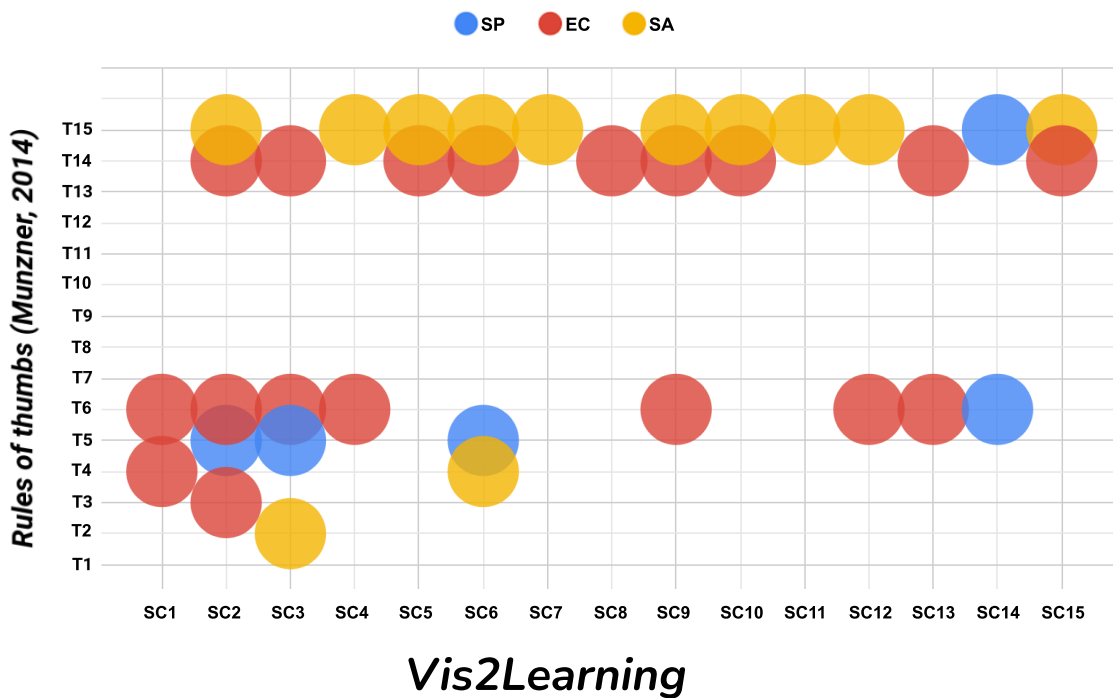

Figure 7. Linking between *Vis2Learning* and Munzners rules of thumbs Munzner (2014)

EC - embedding concepts of a rule of thumb for visualizations in e-learning systems; or **SA** - presented some aspects of a rule of thumb. The rules of thumb and the data generated by the comparison process are available at link[7].

In Figure 7, we observe that all the *Vis2Learning* scenarios (X axis) established at least one connection (represented by bubbles) with Munzner's rules of thumb (Y axis). Note that 18 of the 35 connections presented the category EC (red bubble), indicating that the rules of thumb are embedded by *Vis2Learning*.

An example of this is the **SC9** that brings information about the map chart, it incorporates: a rule of thumb **T6** with guidelines on highlighting a location selected by the user through interaction; **T14** with suggested functionalities of zoom to guide the user observing the relevant data according to a filter; and **T15** with the guideline of applying tones of the same color to maintain the quantitative semantics of the visu-

alization through contrast in scenarios that do not favor the differentiation of colors. The **SC2**, **SC3**, **SC6** and **SC9** scenarios stand out for each embedding three or more aspects of the rules of thumb.

The focus of Munzner's work (2014) is on the user's interactions with the visualizations, however, its content is abstract and has no guidelines on the use of visualization formats in specific contexts. The connections between the rules of thumb and the *Vis2Learning* suggest that the guidelines presented in this article covers the work of Munzner (2014), with the difference of having information on the applicability of contextualized visualizations for e-learning systems.

8   Conclusion

This article presented *Vis2Learning*: a scenario-based set of guidelines for applying visualizations about educational data

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[7] https://docs.google.com/spreadsheets/d/1heg3Hc-w0ZA0VOpNsi43A4kf9We7GaGG1IyYhzVXBu8

in the context of e-learning. Its differential is to recommend visualizations based on applicability scenarios. The guidelines and details that make up the guidelines were developed through a literature review, validated by experts. The comparison of *Vis2Learning* with Munzner's rules of thumb demonstrated that the guidelines are in line with what the author recommends about having a focus on user interactions for the context of data visualization.

We noted, during the evaluation, that teachers tended to disagree about the application of non-traditional visualizations, that is, new visualizations that are normally used (or even known) by the users. However, according to the literature these were the most appropriate visualizations to be applied to the scenarios developed to the evaluation. Our analysis showed that more experience in teaching (more than 6 years, according to our analysis) does not necessarily influence the teachers' knowledge about the use of visualizations to gather information. However, the experience on visualizations in education systems promoted a high level of agreement of Vis2LCharts. With this, we observed that informing the users about the charts' characteristics is as important as ensuring that the visualizations are appropriate for the context.

As future work, we intend to create an online repository with information about the use of the visualization formats covered by the guide, providing end-users with a help link about each chart. To mitigate problems related to the use of visualization formats that are little known by the end-user, we intend to expand the guidelines, considering the preferences of user groups. Also, we intend to expand the investigation with end-users to generate artifacts that allow transforming the guidelines into a catalog of design patterns.

Acknowledgements

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