





Vis2Learning: A Scenario-based Guide to Support Developers in the Creation of Visualizations on Educational Data

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Keywords: Information Visualization, InfoVis, HCI, User Evaluation, e-Learning, Educational Data.

Abstract: Information Visualization provides techniques to build graphics representation that enhance human perception from data. In educational data area, visualizations support professionals to analyze a great amount of data to then make decisions to improve the learning-teaching process. However, the visualizations of educational data often do not fulfill the needs of the end-users. In this paper, we present a scenario-based guidelines for the development of visualizations in e-learning context. For each scenario, we provide the chart format, describe its aim and characteristics and gives examples of its application in the e-learning context. Besides, we provide recommendations to bring improvements to the data visualized from the users interaction with that chart. We conducted an evaluation with 26 participants divided into two groups where one of them used our guidelines and the other did not. Our results revealed that the participants who used the guidelines were more successful in building the visualizations. They reported that the guidelines allow them to be concentrated on the main purpose of the visualizations. We saw that the participants background on e-learning or on the use of charts did not have influence in the building of suitable solutions which reinforce the usefulness of our guidelines.

1 INTRODUCTION


Information Visualization (InfoVis) area proposes methods and techniques to assist the construction of visualizations that are more adherent to the needs of a target audience (Ware, 2012). From the point of view of Human-Computer Interaction (HCI), InfoVis aims to provide users with better graphics representation to enhance human perception using data (Ware, 2012; Munzner, 2014). The main focus of InfoVis is to create visualizations that amplify the user's perception to facilitate the decision-making process based on data observation and prevent users from employing excessive efforts to interpret data (Card et al., 1999; Ware, 2012).


The use of charts differs from the visualization of data in flat tables, as the latter does not assist users to infer patterns, find trends or outliers (Card


and Jacko, 2012). One of Infovis premisses is the use of graphical representations to obtain information from the recognition of visual patterns (Carneiro and Mendonça, 2013).


The design of visualizations are highly attached to the domain of data, because its main purpose is to show data to specific users that want to achieve particular goals. Tervakari et al. (2014) report that visualizations for educational context need to show relevant information in a simple and straight way without requiring users to know statistics. Majumdar and Iyer (2016) point out that visualization-based tools are more suitable for the analysis of educational data, since the data are numerous and complex to be understood without proper treatment (Reyes, 2015). According to the literature, educational data comprises information such as grades, demographic data, frequency of access, delivered activities and other data related to student's interactions with materials (Jordão et al., 2014; Tervakari et al., 2014; Vieira et al., 2018).

The literature points to a gap in investigations on methods and techniques that help the development of visualizations that are adherent to the e-learning

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context and fulfill the users' needs at the same time (Schwendimann et al., 2017; Vieira et al., 2018). For being a learning modality that involves computer systems, e-learning environments handle large amounts of data related to students' interaction with materials. The purpose of appropriate visualizations in this context allows educational professionals (i.e. teachers, coordinators) to have relevant information for tracking and assessing students' performance. With this information, these professionals are able to make more precise decisions about learning and teaching processes (Schwendimann et al., 2017).

Considering the gaps presented in the literature, we propose a set of guidelines that supports developers and designers developing visualizations in the educational context. Our proposal differs from other visualization guidelines to provide recommendations to scenarios applied in the educational domain. We designed the guidelines from lessons learned found in the literature concerned on visualizations in the education context. We also validated our proposal with three specialists in the HCI and Computers in Education area.

We performed a study with 26 participants divided into two groups. One of these groups built visualizations by considering the guidelines, the other did not use the guidelines. We gathered the two groups' perceptions regarding the easy and difficult points for building the visualizations. Besides, the group that used the guidelines answered a questionnaire about perceptiveness of ease and usefulness of the guidelines.

2 RELATED WORK

Many studies concentrate on the definition of processes for creating visualizations from educational data. However, little has been done in terms of proposing guidelines that support developing these visualization, as we can see below.

Conde et al. (2015) and Maldonado et al. (2015), proposed a workflow for preparing visualizations whose data came from learning analytics (LA) algorithms. Conde et al. (2015) present a 4-stages process: (1) identify the characteristics of the expected results; (2) assess what data is needed; (3) select the algorithms that will manipulate the data and which visualizations will be used to report it; and (4) collect the user's impressions to generate new products. Whereas Maldonado et al. (2015) defines a process focused on evaluating tools that can be used to provide visualizations. To develop solutions for MOOCs (Massive Open Online Courses), Chen et al. (2016)

propose an iterative process in which visualization prototypes are successively refined through interaction with experts (not with end-users).

Considering specific proposal of visualizations, Ruipérez-Valiente et al. (2016) present a process composed of the analysis of teaching materials available in an online learning environment and interviews with stakeholders to choose the most suitable visualization. Issues regarding users' context and/or preferences are not considered in the process of choosing the visualizations. Park et al. (2017) developed a dashboard for students and teachers to follow the learning process using e-books. The visualizations prototypes were based on related works that performed usability tests. The prototypes were presented to the interviewees for them to choose the best option.

Taking into account end-users in the construction of visualizations in general, Victorelli et al. (2019) propose a mixed approach between the use of guidelines and participatory design to engage stakeholders throughout the development process. As a result, the visualizations developed under the proposed process were more adherent to the users' needs. However, the stakeholders classified the approach as inadequate, as the process was considered costly because it consumed a lot of time with several long meetings that required a lot of availability from everyone involved. In the context of educational data, Klerkx et al. (2017) proposes a guideline to assist the construction of visualizations to analyze the path of learning. The authors define which data is relevant to evaluate performance and then choose the visualization format, according to the characteristics of the data. However, the proposal does not concern aspects related to the user's interaction with the visualization.

Munzner (2014) defines a *framework* to guide the evaluation and development of visualizations based on the user's data, tasks and domain. The author seeks to raise awareness about the importance of contextualizing the "idiom of visualization" to the user's work. Visualization idiom can be understood as the way in which the user is communicated about the data, and can be perceived by: chart formats; interaction features (eg *zoom* and *pinch*); navigation between different granularity of information; among other features.

The framework proposed by Munzner (2014) has been a reference for the development of investigations in the visualization area. However, the recommendations proposed by the author do not deal with specific visualization formats, but with aspects related to the interaction of users with the use of visualizations. In addition, the recommendations do not have a specific context and target audience, and are presented throughout the different chapters of the book, requir-

ing the complete reading of the work.

3 Vis2Learning

Our guidelines are based on scenarios to assist the development of educational data visualizations in e-learning contexts. It has 15 scenarios for applying visualizations within the e-learning context (see Table 1 for common charts and Table 2 for advanced charts). Each scenario describes a situation where a particular chart can be applied with no repetition of chart format for each scenario. For each scenario, the following information is provided: the most suitable chart and its main characteristics and examples of application (first table column); and general recommendations to bring improvements to the data visualized from the users interaction with that chart (second table column).

The guidelines were built in a contextualized way based on lessons learned from the literature during the development and evaluation of educational data visualizations for e-learning environments. All the process of guidelines construction is available in previous work of the authors (Macedo et al., 2020). In this paper, we will describe the steps of the guidelines construction briefly. For the conception of the guidelines, a rigorous literature search was carried out following the Systematic Literature Review Method. The search string was applied on five scientific papers' search engine, returning 1207 papers. After applying the inclusion and exclusion criteria and the analysis of the title, abstract and conclusion of all the papers, 12 papers were considered relevant to our proposal. They were fully read for extracting the lessons learned presented in each paper, regarding the design and/or evaluation of educational data visualizations. The extracted information were consolidated and submitted to the evaluation of three specialists in HCI and Computers in Education. From the validation, we refined the guidelines to its current version.

4 EVALUATION

We evaluated the use and the acceptance of our guidelines. In our study, two group of participants representing developers/designer constructed prototypes of charts considering scenarios of use in e-learning context. Only one group used the guidelines. Our evaluation was guided by two research questions: *(RQ1) How did the participants of both groups build the visualizations?*, and *(RQ2) What are the participants' feedback about the guidelines?*. For the RQ1, the aim was to understand the strategies the participants took

to produce their solutions, including those that used the guidelines. From RQ2, we explored the acceptance of the guidelines in the participants perspective. Our study was approved by the ethical committee of UFSCar with protocol number 4105750. Our study follows the methodology proposed by Wohlin et al. (2012). We will present the planning, execution, analysis and threats to the validity of our study in the next sections.

4.1 Planning

Taking into account our RQs, we started by planning a set of artifacts to support our study.

First, we created two scenarios of use (SU). To fulfill the scenarios, the visualizations should be constructed taking into account our guidelines. The first scenario of use (SU1) followed the guideline SC2 (see Table 1) and described a teacher's need to visualize the final grade of students, composed of four partial grades. The second scenario of use (SU2) followed the guideline SC6 and described the teacher's needs to know the time students take an exam, and the average time to answer each question. The teacher had to create one chart per student.

We also selected a tool for the prototyping of the visualizations. We set five requirements that the selected tool should fulfill. The requirements are: R1 - to work via a browser; R2 - allow the editing of the tooltip text; R3 - allow the editing of the subtitle of a chart; R4 - allow changes in colors and the transparency inside charts; and R5 - allow the use of colors and patterns to differentiate groups of data in charts. Besides, the tool should not demand expertise in programming.

We tested the selected tools to see if they allowed to apply SU1 and SU2, following the guidelines SC2 and SC6, respectively. We got the recommendations about the tools in JUSTINMIND blog (JUSTINMIND, 2020) and applied our set of requirements. After analysis of basic characteristics, four tools were chosen and evaluated according to the five requirements mentioned above. The results can be seen in Table 3. The two last columns show whether the SUs could be applied or not, by using these tools. After the analysis, we chose AMCHARTS as the most suitable tool to our purposes. After selecting the tool, we developed the templates for the SU1 (see Figure 1 - A) and SU2 (see Figure 1 - B), following the guidelines. The two templates served as baselines for comparing with the solutions produced by the participants of the study.

We also created an online feedback questionnaire based on the Technology Acceptance Model (TAM)

Table 1: Vis2Learning - Scenarios with common charts - Identification:: id, chart's name, and its purpose; Characteristics: the main chart features in the education data context; Recommendations:: how the interaction with the chart can be improved.

| Identification :: Characteristics | Recommendations |
|--|---|
| (SC1) Pie chart - Distribution of student data in pre-planned categories :: (i) Aim : represents the proportion in relation of the whole; (ii) Chart characteristics : pie chart provides an overview about proportions of the chosen variables (i.e. slices) in relation of the whole (complete pizza = sum of the slices); it is mandatory that the variables represented (i.e. slices) add 100 % in whole; (iii) Example of application : illustrate proportions of the evasion rates; visualization of students' demographic and profile data (e.g. education level, age, gender). | (i) Exact value : as this chart often hides the real value of each slice, tooltips or legends are recommended to present the real value; in charts composed by many different categories, captions are suitable to show the total value of each category; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : stand out the slices of the categories selected by users; (iv) Specificities : it is recommended do not use more than 5 different categories for data classification to prevent the legibility issues which can be caused by overlapping of slices or even by the use of small fonts; in cases with more than 5 categories the recommendation is to present the 4 main ones and agglomerate the others by labelling as "others". |
| (SC2) Horizontal bar chart - Representation of the total amount of data for a category :: (i) Aim : shows quantitative values of X-axis identified by the categories presented at Y-axis; (ii) Chart characteristics : in aggregate viewing, the bar of each category is composed of two or more small bars arranged on the top of each other to represent the idea of parts of the whole; however, the aggregate viewing is suitable only in cases that by adding the individual values of each small bar it has the representation of a total; nevertheless this total does not necessarily bring information for the analysis; horizontal bar chart fits to illustrate timeline visualizations where the X-axis represents the timeline while the bars arranged from the Y-axis represent quantitative values; (iii) Example of application : show how students' averages are composed in a course, from an aggregate viewing, where each full bar represents the total grade of a student and each piece of the bar outlines a component of the total grade (e.g. tests, tasks, assessments, activities in group). | (i) Exact value : real values are displayed from tooltips by positioning the mouse over the bars or the captions; (ii) Filtering data mechanisms : allows the visualization of students' individual data; (iii) Highlight data : as a student is selected, display in the foreground the full bar (i.e. highlight the bar); (iv) Specificities : in agglomerate mode bars, colors and patterns (e.g. scratches, dots, dashes) are applied to demonstrate clearly what is the size of each piece of the total bar; the use of 3D bar format is not recommended due to it can insert difficulties for users comparing the different data. |
| (SC3) Vertical bar chart - Comparison of values one each other, or with an average or target value :: (i) Aim : represents quantitative values of Y-axis identified by the categories assigned in the X-axis; (ii) Chart characteristics : it has the same characteristics of horizontal bars however in a vertical mode; (iii) Example of application : illustrate to students information from their performance compared to the average of the class to support them in managing their needs of learning; this visualization motivates students to review, if they need, their learning strategies with the aim of getting better outcomes. | (i) Exact value : display the real value from tooltips by positioning the mouse over the bars or the captions; (ii) Filtering data mechanisms : provides the option of visualizing students' individual data; (iii) Highlight data : as a student is selected, display in the foreground the full bar (i.e. highlight the bar); make clear the difference among the bar by applying colors and patterns; (iv) Specificities : as in vertical bar chart, the use of 3D bar format is not recommended. |
| (SC6) Area chart - Illustrates the midway students' outcomes showing the evolving and data changings over time :: (i) Aim : represents variables associating them to progress viewing (e.g. percentage completed, time elapsed); (ii) Chart characteristics : a continuous line passes through all the crossing points presented between the X and Y-axis; the use of several lines is suitable to describe different groups of data; it is recommended to the X-axis to contain the progress scale (e.g. time, steps), and to the Y-axis, the quantitative variables; (iii) Example of application : provide to students 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 pace of studies and consequently make adjustments if they need; as well visualize the performance of work-groups versus an expected outcome to search for difficulties that they could have in one activity. | (i) Exact value : display from tooltips the real values when users hover the mouse on the chart; (ii) Filtering data mechanisms : provide ways to see data of particular students; (iii) Highlight data : in cases of multiple variables representation, colors with transparency are recommended to avoid the missing of information caused by the overlapping of areas, for instance; (iv) Specificities : use patterns (e.g. dots, dashes) to contrast the areas in cases of 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 format of the lines in captions. |
| (SC8) Wordcloud chart - Illustrates terms most used in courses or in forum discussions :: (i) Aim : represents the occurrence of terms within a sample of words; (ii) Chart characteristics : it encodes few variables and the font size of each word indicates its number of occurrences in that sample without showing its real value; the chart often is constructed in real-time easily; the analysis of data from this chart type is subjective as the exact value of each word is expressed by the font size of the word; (iii) Example of application : wordclouds help teachers on explaining the understandings of those terms that the class have; it is useful to link the discussions of forum posts to the wordcloud chart; it allows visualizing the questions that received the most correct answers by the students. | (i) Exact value : captions or tooltips provide the value of the occurrences and their classification (e.g. 250 times, 3rd most repeated word); (ii) Filtering data mechanisms : option of removing words from the cloud; (iii) Highlight data : usually not applied; (iv) Specificities : usually not applied. |
| (SC9) Map chart - Represents data from the geographic localization of students :: (i) Aim : represent the distribution of data related to the geographic position (e.g. countries, states, cities); useful for distance learning courses; (ii) Chart characteristics : the world map is often the format of representation where the regions of the map get the focus according to the needs of data or users; the color shades are applied to illustrate the quantitative data and the colors tones give the perception of having a great or less amount of data in that map region; (iii) Example of application : allows the visualization of rates on dropouts, retentions or approvals by location. | (i) Exact value : by positioning the mouse over a map region, tooltips provide the real value; (ii) Filtering data mechanisms : zoom in allows to see details of some location (e.g. users can see data from particular schools in some region of a city); (iii) Highlight data : put in the foreground a location selected by users; (iv) Specificities : shades support the perception of amount of data for the same color (e.g. bold colors express more retention than the light color). |
| (SC15) Bubble chart - Provides an overview involving 3 variables (X, Y and Z) where X and Y are categories and Z is quantitative number :: (i) Aim : represent a quantitative variable (bubble size) distributed in a categorical plane (i.e. X and Y); (ii) Chart characteristics : while a bubble depicts the crossing point of X and Y (i.e. categories descriptions) the bubble size draws the value of a quantitative variable associated with this crossing point; (iii) Example of application : see the engagement of students from the frequency they access the materials and from which source (e.g. personal computer, mobile phone). | (i) Exact value : consider the addition of captions inside the bubbles to provide the exact value whenever the bubble size accommodate it. For small bubbles use tooltips; (ii) Filtering data mechanisms : allow the selection of which students will have the data shown; (iii) Highlight data : stand out a bubble according to the category selected by users; (iv) Specificities : the bubble colors can encode a 4th variable. |

(Davis, 1989). TAM questions are divided into the dimensions of ease-of-use perception and usefulness perception. The ease-of-use is related to the perception that a technology can be adopted with no efforts. The perceived usefulness represents how much a person considers that the use of a specific technology may improve their performance. We also added an open question about the guidelines in the feedback questionnaire.

4.2 Execution

We carried out an evaluation with 26 participants, 4 graduated and 22 undergraduate students of a Human-Computer Interaction course at the Federal University of São Carlos (UFSCar) - campus Sorocaba.

All participants filled an informed consent form to take part in the study. Before the study session, the participants answered a profile questionnaire which supported us in dividing them into groups. In this questionnaire participants were asked about (a) their experience with programming languages, InfoVis, and the tools that would be used in the evaluation; (b) their experience as developers; (c) where they were

used to handle charts; and (d) where they searched for information about the application of charts. Table 4 shows the participants' responses. Each participant is identified by ID followed by the group they were in (i.e A or B). The participant D-26 was the only one not to answer the profile questionnaire. We used the information collected by the profile questionnaire to assign participant to each groups in a balanced way. Participants in group A used the guidelines, while participants in group B did not. The participants that already used the chosen visualization tool were assigned to group B, in order to avoid that their previous expertise biased the results.

The evaluation took place in a computer lab at the UFSCar which had tables arranged in rows and divided into two parts by a central corridor. We divided the participants per groups on the right side (i.e. group A) and on the left side (i.e. group B). All the participants had the same infrastructure resources, i.e. institution's computers to perform the required activities.

Before starting the activity of prototyping, the participants took part of a warm-up session where one researcher presented (i) the fundamentals of educa-

Table 2: Vis2learning - Scenarios with advanced charts - Identification:: id, chart's name, and its purpose; Characteristics: the main chart features in the education data context; Recommendations:: how the interaction with the chart can be improved.

| Identification :: Characteristics | Recommendations |
|---|---|
| (SC4) Violin plot - Identification of subgroups from the distribution of data quickly :: (i) Aim : represents the distribution of a data set correlated to a variable through scale (i.e. minimum to maximum values); (ii) Chart characteristics : in violin plot, the data is disposed along a line depicting the values; data relates to one single variable, but with different identifiers; it enables the visualization of subgroups from the data without applying equations or algorithms; (iii) Example of application : show students' grades in one activity or course to identify subgroups as such as students who fail or pass; or show the number of students positioned above/below of the class average (or any other grade). | (i) Exact value : display from tooltips the real values when users hover the mouse on the violin plot border; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : stand out the dot on the line related to the selected data (i.e. a student); (iv) Specificities : colors and patterns are applied to delimit data ranges and are enabled by user interaction. |
| (SC5) Radar chart - Illustrating data of the different students' interaction versus a material :: (i) Aim : represents the value of 3 or more quantitative variables that have a common identifier (e.g. grades, the variables and a particular student, the identifier); (ii) Chart characteristics : this chart contains axes, lines and data points, where the axes represent the scale values for each variable; the line that connects all the axes represents a data set; and the data point in the axis that the line touches represents the data value of that variable attributed to group that the line represents; one chart can include several lines, and each one represents a set of data being differentiated by colors; a 3rd variable is represented by adding a bar chart in the center of radar chart; (iii) Example of application : see grades from student workgroups that performed the same activities; it provides a feedback to the groups about which activities they should put effort to improve their knowledge on a topic; observe whether there was a balance in the composition of workgroups concerning on students performance. | (i) Exact value : display from tooltips the real values when users hover the mouse on the chart; (ii) Filtering data mechanisms : provide ways to see specific students or workgroups; (iii) Highlight data : stand out the line linked to the selected student; (iv) Specificities : patterns (e.g. dots, dashes) in the format of the lines are recommended as a way of identifying and distinguishing data in cases of colors are not available; provide the meaning of the colors and formats of the lines in the captions. |
| (SC7) Activity network diagram - Represents the instructional design of courses or steps of workgroup projects :: (i) Aim : shows the paths taken the execution of steps; (ii) Chart characteristics : the shapes depict activities and the arrows the movements from one to another step; the chart main purpose is not the representation of quantitative data; (iii) Example of application : the chart provides the linear visualization of activities arrangement supporting teachers in detecting issues from the activities to then they make improvements; for instance, from the visualization teachers can observe whether some element affect all the activities flow as well as analyze the relevance in the order that activities are performed. | (i) Exact value : usually not applied; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : usually not applied; (iv) Specificities : colors and line patterns are assigned to arrows to indicate, for example, steps where delays or problems arisen during the activities executions; captions provide the meaning of the colors and line patterns adopted. |
| (SC10) Heatmap chart - Illustrates the performance of large groups of students :: (i) Aim : represent information from 3 variables, being X and Y categories and Z the quantity or category; (ii) Chart characteristics : the chart is built on a cartesian plane where the data crossing point X and Y are assigned with a color that denotes the 3rd variable (i.e. Z); in each cell instead of using the absolute value in the standard format, this chart employs colors which facilitates the detection of patterns of data; another representation of this chart is on pictures where X and Y are coordinates and Z represents the number of times that point was observed; (iii) Example of application : visualization of students' performance and the identification of common characteristics based on the colors (e.g. all students who failed in an exam). | (i) Exact value : by positioning the mouse over a cell, tooltips show the exact value; captions show the absolute value inside the cell; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : usually not applied; (iv) Specificities : patterns (e.g. scratches, dots, dashes) is an alternative in replacing of the use of colors to differentiate and identify data; the use of captions to report the meaning of formats and colors employed in the chart. |
| (SC11) Treemap chart - Shows the data about the students' participation categorized by topics and ordered by a raking :: (i) Aim : represent data that follows a well-defined hierarchical distribution; the viewing of total are got by adding each; (ii) Chart characteristics : rectangular shapes represent the data, but there area alternatives to plot in circular formats as pie charts, it often occupies all the area available for it; treemap provides an overview with the existing hierarchy in the data and the percentage that each category represents in the whole; (iii) Example of application : see the number of topics discussed in forums in a distributed or ranked way, being possible to observe the most commented topics. | (i) Exact value : by moving the mouse over the rectangles, tooltips show the real value; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : usually not applied; (iv) Specificities : color shades are applied to illustrate the larger and smaller samples of data. |
| (SC12) Scatter plot - Shows a comparison of datasets (e.g. students' grades) to illustrate the cause-effect from the application of a teaching-learning method :: (i) Aim : represents two or more datasets (Y) that are related to a categorical variable (X) to observe the relationship between two groups; (ii) Chart characteristics : this chart compares two datasets displayed by dots which are plotted at the intersection of X and Y-axis in a cartesian plane; whether only one dataset is used it represents a dot plot; scatter plot is not suitable for overviewing of high-density data due to the large volume of data can cause overlapping of lines or high density of dot clouds; (iii) Example of application : compare students' grades from activities executed online and offline mode to uncover patterns in relation of the mode applied; compare the average of students to the time spent on activities; observe the differences on the performance among students. | (i) Exact value : by moving the mouse over the dots, tooltips reveal the value for X and Y; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : usually not applied; (iv) Specificities : for each dataset, dots have different colors and shapes (e.g. group A represented by green circles and group B by blue triangles); a matrix of scatterplots is a well-representation for cases that there are more than one pair of variables; captions report the meaning of formats and colors employed in the chart. |
| (SC13) Q-Q plot - Compares a group of students performance with baseline values :: (i) Aim : represents the distribution of data; (ii) Chart characteristics : the X-axis contains the performance measures and the Y-axis the baseline values; this chart is suitable to confirm and illustrate the existence of subgroups of data when used together with violin chart; (iii) Example of application : from the students' grades are possible to identify subgroups (e.g. groups of failed students or passed students); check whether the level of difficulty of activities are balanced. | (i) Exact value : by pointing the mouse over dots, tooltips show the values of X and Y, and the student's name; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : stand out the point correspondent to the student selected by users; design a line as a baseline value to show the groups of data which are close or far from the line (e.g. the line show the minimum average of approval and the points above the line represent the approvals and the below the retentions); (iv) Specificities : usually not applied. |
| (SC14) Hexbin plot - Compares datasets with a large volume (high density) of data to find out patterns :: (i) Aim : represent data from 3 variables (i.e. X and Y are categories and Z is the quantitative value or category); (ii) Chart characteristics : a hexagon represents the crossing point between X and Y values and the color encodes the Z value; the "dots" are replaced by hexagons so that the data is not overlapping and fits in all the space available without having no-used spaces; (iii) Example of application : visualize the student session in a Learning Management System and their grades. | (i) Exact value : by pointing the mouse over a chart point, tooltips show the value for X and Y, and the student's name; (ii) Filtering data mechanisms : usually not applied; (iii) Highlight data : shaded borders help to delimit data in neighbor hexagons that often is close due to the high-density of data; (iv) Specificities : by combining colors and captions, the data representation meaning informs the larger and smaller samples of data; use patterns (e.g. scratches, dots, dashes) in cases that colors are not available. |

Table 3: Evaluation of tools based on the five requirements.

| Tool | R1 | R2 | R3 | R4 | R5 | SU1 | SU2 |
|--------------------------|----|----|----|----|----|-----|-----|
| Chartblocks ¹ | OK | - | - | OK | - | OK | - |
| Plotly ² | OK | - | OK | OK | - | OK | - |
| Datawrapper ³ | OK | - | - | OK | - | OK | - |
| AMCHARTS ⁴ | OK | OK | OK | OK | OK | OK | OK |

tional data and InfoVis (Munzner, 2014; Ware, 2012), and conducted a (ii) hands-on exercise by using the AMCHARTS tool to explore its resources. Besides, the researcher pointed out the activity objective and all the steps the participants should follow during the evaluation. After the warm-up, the participants carried out the prototype activity. All the participants (i.e. groups A and B) built prototypes of both SUs. The participants in group B, i.e. who did not use our guidelines, were free to search for information about the charts on the Internet.

After building each chart, participants should submit, to an online platform, the source code automatically generated by AMCHARTS; the list of references used to produce the visualization and the reason for

using it (in the case they searched for information on Internet); and the description of the difficulties s/he faced. Each participant should pack all this information in a single file and submitted it. Only participants in group A answered the feedback questionnaire (i.e. TAM questions) at the end of the study.

4.3 Analysis

We explored all the prototypes produced by the participants and the answers from the feedback questionnaire. Table 5 shows the details of our analysis for each scenario of use (SU1 and SU2) per participant. First, we checked the chart format the participant used and the recommendations each one applied (about the use of tooltip, 3D, and so on). We also verified whether the participant's solution was suitable to the scenario of use, using our templates as baselines.

After examining the participants' visualizations, we concentrated on exploring the participants' comments as well as the references they used to construct

Table 4: Participants profile — (a) Knowledge: (1) I’ve never heard of; (2) I have theoretical knowledge; (3) I have practical and theoretical knowledge; (4) I have deep knowledge — (b) Exp: (2) I programmed only at school; (3) I’ve worked with programming; (4) I currently work with programming — (c) 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 — (d) Information about charts: (1) I don’t use, (2) I seek tips on the internet; (3) I’m looking for ready examples, (4) I search for guidelines that have detailed descriptions of charts usage.

| Identification | | | (a) Knowledge | | | | | (b) Exp | (c) Use of charts | | | (d) Information about charts |
|----------------|-----|------------------|---------------|----|--------|---------|----------|---------|-------------------|-----------|---------|------------------------------|
| ID | Age | Higher education | HTML | JS | Charts | InfoVis | AMCHARTS | Dev | Personal use | At school | At work | |
| D1-B | 23 | Complete | 3 | 3 | 2 | 1 | 1 | 3 | 1 | 2 | 2 | 2;3 |
| D2-B | 21 | Incomplete | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 2;3 |
| D3-B | 22 | Incomplete | 4 | 4 | 3 | 3 | 3 | 2 | 4 | 4 | 3 | 2;3 |
| D4-B | 34 | Complete | 4 | 3 | 3 | 3 | 1 | 4 | 3 | 3 | 3 | 2;3 |
| D5-A | 22 | Incomplete | 3 | 3 | 2 | 1 | 1 | 4 | 2 | 3 | 1 | 2;3 |
| D6-A | 21 | Incomplete | 3 | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 2;3 |
| D7-B | 20 | Incomplete | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 |
| D8-A | 35 | Complete | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2;3 |
| D9-A | 21 | Incomplete | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 1 | 2;3 |
| D10-A | 23 | Incomplete | 3 | 3 | 3 | 3 | 1 | 4 | 2 | 3 | 3 | 1 |
| D11-A | 21 | Incomplete | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 1 | 2;3 |
| D12-A | 22 | Incomplete | 3 | 3 | 2 | 2 | 1 | 4 | 4 | 2 | 1 | 2;3 |
| D13-A | 21 | Incomplete | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2;3 |
| D14-B | 22 | Incomplete | 4 | 4 | 3 | 2 | 1 | 2 | 2 | 2 | 1 | 2;3;4 |
| D15-A | 24 | Incomplete | 2 | 2 | 2 | 2 | 1 | 4 | 1 | 1 | 1 | 3;4 |
| D16-B | 20 | Incomplete | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | 2;3 |
| D17-B | 21 | Incomplete | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 3 | 1 | 3 |
| D18-A | 27 | Complete | 3 | 3 | 4 | 1 | 1 | 4 | 4 | 2 | 3 | 2;3;4 |
| D19-B | 24 | Incomplete | 3 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| D20-A | 21 | Incomplete | 4 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 |
| D21-B | 22 | Incomplete | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 3 | 3 | 2 |
| D22-B | 22 | Incomplete | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2;3 |
| D23-A | 25 | Incomplete | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2;3 |
| D24-B | 20 | Incomplete | 3 | 3 | 1 | 1 | 1 | 4 | 2 | 2 | 2 | 3 |
| D25-A | 26 | Incomplete | 3 | 3 | 3 | 2 | 1 | 4 | 2 | 1 | 2 | 2;3 |

the solutions. This allowed us to observe the steps taken and the problems encountered by the participants during the process of choosing the visualizations’ formats. From this analysis, we could notice the difference between the problems listed by the participants in groups A and B. Finally, we explored the participants’ responses (group A, only), regarding the acceptance of our guidelines.

4.4 Threats to Validity

There are four threats to validity determined by Wohlin et al. (2012) that we should check in our study, which are: conclusion, construct, internal and external. We will discuss each one as follow. The elements to mitigate these threats are described below:

Several sources of information were used to give reliability to our *conclusions from the results*. The following sources were considered: the code generated by the AMCHARTS tool; the visualizations resulting from the codes; the comments made by participants about the strategies they used for constructing the solution; the references used by the participants; and the data collected via the feedback questionnaire. To mitigate *construct* problems, we prepared a set of artifacts that support the application of our study. We also conducted a warm-up session providing the concepts about InfoVis and education data to the participants. A hands-on exercise helped the participants to handle AMCHARTS tool.

To mitigate the participants’ fatigue, an internal validity threat, we adopted the strategy of prototyping solutions and not developing them from programming languages. We used a tool that allowed participants to change all parameters of the visualization without the need to interact with the source code. Besides, all formatted data was provided so that participants could make efforts only in the design of the visualizations. In our study, students represented a sample of developers which could comprise the external validity threat. In the study of Salman et al. (2015), the authors concluded that professionals and students tend to perform similarly when developing new tasks. In the context of our evaluation, only one participant declared to work with visualization development, suggesting that most of the group had no experience with the charts construction even the ones with more experience in development of visualizations.

5 FINDINGS

We present our findings in three sections. In the first two sections we discuss the results that supported us to answer the RQ1 and RQ2 (see in Section 4.1). In the third section, we discuss whether the participants profile had influence or not in our results.

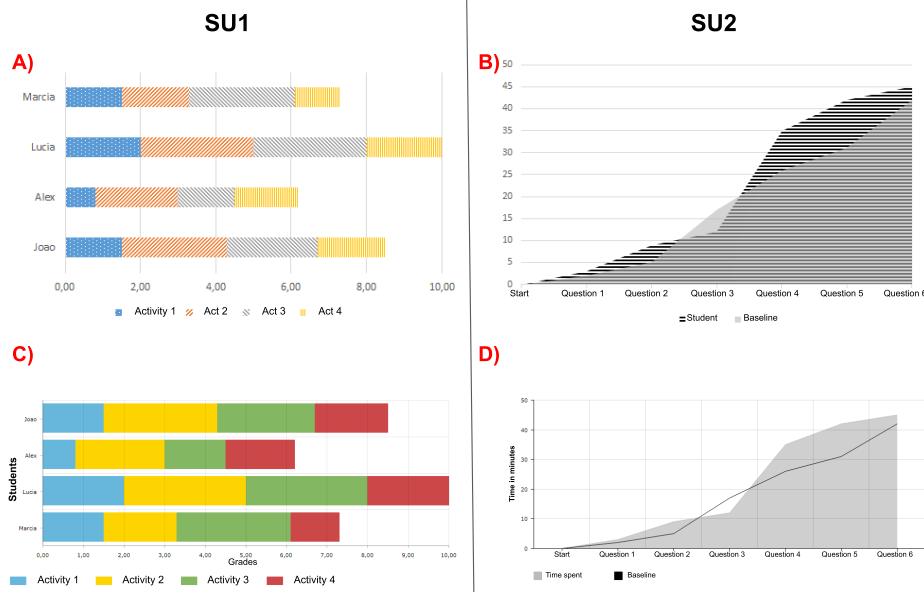


Figure 1: Charts example — A and B baseline developed by the authors — C was develop by participant D25-A and D by participant D20-A.

5.1 RQ1: How Participants Build the Visualizations

From the 26 participants, 11 produced suitable visualizations, considering both scenarios (SU1 and SU2) and, among them, 7 created the visualizations by following the guidelines. However, considering the 26 participants, 8 of them built solutions that did not fulfill any of the two scenarios and, among them, 3 followed the guidelines.

Overall, the participants could develop visualizations for both scenarios. Some solutions were very close to the baseline developed by the authors, such as the solution proposed by participants D25-A and D20-A (see Figures 1 - C and 1 - D). For these solutions, the only recommendation (from the guideline) not applied was the use of patterns or textures to distinguish data.

By exploring the solutions for the scenarios (i.e. SU1 and SU2), our results revealed that all those who developed visualizations for SU1 did not follow the recommendation for using patterns (i.e. visual marks as such dots) to identify elements in the chart. On the other hand, in SU2, the participants applied the patterns. We considered the participants used the patterns because they were informed that the chart would be printed in black and white.

Participants in group B (i.e. the group that did not use the guidelines) reported the elaboration of the visualizations took long due to the lack of guidelines

with tips about how they could apply the different chart formats. For instance, participant D22-B, when developing a solution to SU1, stated that “I was struggling in deciding on what type of charts available in the tool should I use from which I could show the data to that audience in an appropriate way”. The same participant opinion was noticed when developing the solution to SU2: “again my difficulties were concentrated on how to choose, among the chart formats available, the most suitable one to show comparison of information”.

Participants in group B adopted a strategy for searching information about the charts that was close to the organization approach by scenarios, provided by the guideline. These participants extracted keywords from the scenario description (i.e. SU1 or SU2) and looked for the charts by pasting the keywords on internet browsers as reported by the participants D1-B and D4-B, respectively: “To get some examples, I searched on Google Images ‘how to construct charts to show students grades’”, and “I accessed Google Images to explore the types of charts that could be used to present students’ performance.”.

We found out that the participant D11-A decided not to adopt the guidelines even being in group A. The participant stood out taking a testing-based approach by visualizing the different charts available in the tool, until s/he found the suitable one. However, by following this approach, the participant faced difficulties to select what would be the best chart to represent the data, as reported: “[I had] a little difficulty to

Table 5: Results of the participants visualizations — (-1) Not applicable, (0) Not applied, (1) Partially applied, (2) Fully applied — *Use of the 3D format was not appropriate.

| SU1 | | | | | | | SU2 | | | | | | |
|-------|--------------|---------|-----|---------|----------|-----------|-------------------|---------|-----|-------|--------------|----------|-----------|
| ID | Chosen chart | Tooltip | 3D* | Stacked | Patterns | Suitable? | Chosen chart | Tooltip | 3D* | Label | Transparency | Patterns | Suitable? |
| D1-B | bar chart | 1 | 0 | 2 | 1 | Yes | column + line | 1 | 0 | 2 | 2 | 1 | No |
| D2-B | column chart | 1 | 0 | 2 | 1 | Yes | column + line | 1 | 0 | 2 | -1 | 1 | No |
| D3-B | bar chart | 1 | 0 | 0 | 1 | No | line chart | 2 | 0 | 2 | -1 | 2 | No |
| D4-B | column chart | 1 | 2 | 0 | 1 | No | column chart | 1 | 2 | 1 | -1 | 0 | No |
| D5-A | bar chart | 2 | 0 | 0 | 1 | No | area chart | 1 | 0 | 2 | 2 | 0 | Yes |
| D6-A | bar chart | 1 | 0 | 2 | 1 | Yes | area chart | 2 | 0 | 2 | 2 | 2 | Yes |
| D7-B | column chart | 1 | 0 | 2 | 1 | Yes | line | 1 | 0 | 2 | -1 | 2 | Yes |
| D8-A | bar chart | 1 | 0 | 0 | 1 | No | column chart | 1 | 0 | 2 | -1 | 0 | No |
| D9-A | bar chart | 1 | 0 | 2 | 1 | Yes | column + line | 1 | 0 | 2 | -1 | 1 | No |
| D10-A | column chart | 1 | 0 | 0 | 1 | No | column + line | 0 | 0 | 2 | -1 | 1 | No |
| D11-A | column chart | 1 | 0 | 2 | 1 | Yes | line chart | 1 | 0 | 2 | -1 | 2 | Yes |
| D12-A | bar chart | 1 | 0 | 2 | 1 | Yes | column chart | 1 | 0 | 2 | -1 | 2 | No |
| D13-A | bar chart | 1 | 0 | 2 | 1 | Yes | line chart | 1 | 0 | 2 | -1 | 2 | Yes |
| D14-B | column chart | 1 | 0 | 0 | 1 | No | line chart | 1 | 0 | 2 | -1 | 2 | Yes |
| D15-A | column chart | 1 | 0 | 0 | 1 | No | column + line | 1 | 0 | 2 | -1 | 1 | No |
| D16-B | column chart | 1 | 0 | 2 | 1 | Yes | line chart | 1 | 0 | 2 | -1 | 2 | Yes |
| D17-B | column chart | 1 | 0 | 2 | 1 | Yes | area + line | 1 | 0 | 2 | 2 | 2 | Yes |
| D18-A | bar chart | 1 | 0 | 2 | 1 | Yes | area chart | 2 | 0 | 2 | 2 | 0 | Yes |
| D19-B | column chart | 1 | 0 | 2 | 1 | Yes | bar chart | 1 | 0 | 2 | -1 | 0 | No |
| D20-A | column chart | 1 | 0 | 2 | 1 | Yes | area + line | 2 | 0 | 1 | -1 | 0 | Yes |
| D21-B | line chart | 0 | 0 | -1 | 1 | No | overlap bar chart | 1 | 0 | 2 | 1 | 0 | No |
| D22-B | column chart | 1 | 2 | 2 | 1 | No | overlap column | 1 | 2 | 1 | 0 | 0 | No |
| D23-A | bar chart | 1 | 0 | 2 | 1 | Yes | line | 2 | 0 | 2 | -1 | 2 | Yes |
| D24-B | bar chart | 1 | 0 | 2 | 1 | Yes | line | 0 | 0 | 2 | -1 | 0 | Yes |
| D25-A | bar chart | 1 | 0 | 2 | 1 | Yes | line | 2 | 0 | 2 | -1 | 2 | Yes |
| D26-B | column chart | 1 | 0 | 2 | 1 | No | column chart | 1 | 0 | 2 | -1 | 0 | No |

choose between line chart, [...] diagram chart (activity network) or area chart”. After some unsuccessful attempts, this participant started to explore the guidelines and develop suitable solutions for SU1 and SU2. This participant also realized that some choices that seemed natural at first, did not match the scenario’s needs (i.e. SU1 and SU2). At the end of the evaluation, the participant declared “I found it interesting to apply these concepts [of the guidelines], because even though it seems intuitive when looking at visualization models [format], in practice we should consider a set of requirements before constructing the visualization to make the data interpretation more intuitive”.

Even using the Internet to search for examples and tips, the participants in group B reported a lack of confidence to choose a chart type, as we could as reported by participant D1-B: “As I do not have much knowledge about which chart is the most appropriate, I was very confused at the time of choice and I ended up trying different charts until I found out the one that could be the best to visualize that information”.

Finally, we could notice that some participants in group B (i.e. D7-B, D14-B, D16-B, D17-B and D24-B) who did not have access to the guidelines, were able to produce visualizations that fulfill practically all the recommendations available in the SC6 (see Table 1). By checking the profile of these participants (see Table 4), we saw they have a preference for seeking ready-made tips and examples on the Internet, based on the context of the scenario. In particular, the participant D24-B has already worked on the construction of charts for web applications.

Participant D1-B, who had experience in the development of visualizations, stated difficulties because the visualization design is often handled in a generic perspective without looking the data domain characteristics. The participant reported “I’ve never made an effort to think on how the design of the visualization can impact the end-users... As a developer, I’ve taken the trial and error approach to see what is the best one, but I realized that some charts may not give the user any information or may not present it more effectively what the user needs to see”.

5.2 RQ2: Feedback of the Guidelines Acceptance

Taking into account the responses collected from the participants in group A, i.e. those who used the guidelines, we explored the feedback regarding the perceived usefulness and ease-of-use of the guidelines (see Table 6). We used a Likert scale of four point as answer options, ranging from *strongly disagree* to *totally agree*. Figure 3 and Figure 2 illustrate the results of the acceptance feedback. We also considered the comments added by the participant in the open question of the questionnaire.

Figure 2 shows that for the questions F1 and F2 (see Table 6) only 3 of 13 participants reported to have difficulties related to the learning about the recommendations. From this result, we could understand that the guidelines provide information enough to the individuals guide themselves to building visualizations and that it does not require training for its use. We want to restate that we did not provide any

Table 6: Feedback questionnaire.

| Dimension | ID | Question |
|--------------------------|----|--|
| Perceived of Usefulness | U1 | Using the guidelines allowed me to choose the visualization format more quickly. |
| | U2 | Using the guidelines improved my perception of good practices for building visualizations. |
| | U3 | Using guidelines is important and adds value to my work. |
| | U4 | Guidelines made the result of the visualization more interesting. |
| | U5 | I find the guidelines useful for developing educational data visualizations. |
| Perceived of Ease-of-use | F1 | It was easy to learn how to use the guidelines. |
| | F2 | I find the guidelines easy to understand. |
| | F3 | I find it easy to apply the guidelines. |
| | F4 | Using guidelines makes my work easier. |
| | F5 | Guidelines allow flexibility for the development of visualizations. |

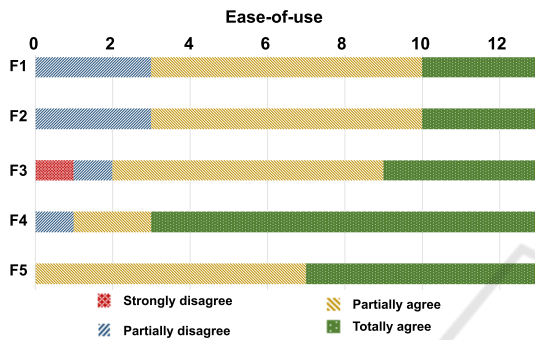


Figure 2: Participants’ feedback on the perceived ease-of-use.

explanation or training on the guidelines to the participants of the group, being the evaluation activity the first contact of that group with them.

Taking into account the answers of the questions F4 and F5, we see a high degree of agreement about the usefulness of Vis2Learning to guide the participants in building of their solutions in a flexible way. According to the participant D6-A, “the guidelines provide a set of recommendation which explains the best way to apply each chart type... this kind of knowledge is not easily found any other place... the guidelines are well-organized and contain full details on how to use the charts”. The participants in group A considered, in general, that the guidelines provide information regarding the characteristics of the visualization formats, focusing on the most relevant points of the data visualization. Participant D5-A mentioned: “the guidelines supported me choosing the suitable chart for each type of data that I wanted to present, keeping the focus on the proposed scenario”.

Taking into account the easy-of-use dimension (see Figure 2), F3 was the only question that received a “totally disagree” answer. We observed that the disagreement came from participant D15-A, who informed, in the profile questionnaire, to have never used charts to design visualizations. Besides, the participant mentioned that was struggling to use the AM-CHARTS tool. D15-A demonstrated the frustration

with the prototyping tool during the development of the solutions for SU1 and SU2, as shown in the following quotes: “First I chose the radar chart [...] but I couldn’t plot it on the tool”, and “[...] for me the biggest block was to be able to fix the labels [...]”.

In Figure 3, we see that the participants considered the guidelines useful to support the design of visualizations in the educational context. Both questions U5 and U2 got a high level of agreement on the usefulness of the guidelines as can be seen from the comment of participant D12-A: “The guidelines really helped me making a reflection on the possible problems and benefits of using each type of chart”.

There was no consensus on questions U1, U3 and U4. Considering the responses for U4, we notice that 10 out of 13 participants agreed that the guidelines supported them building visualizations which relevant results. By looking to the positive answers for question U1 (10 out of 13), we saw that the information about the context of use for each chart present in the guidelines, aided the participants in the solution design as mentioned by the participants D5-A and D8-A, respectively: “the examples of how to apply each chart were essential to make my decision about the best visualization for the data.”, “the examples were really important for the selection of the best chart.”. For U3 only participant D15-A disagreed. By examining our results in-depth, we observed that all *totally disagree* answers in the usefulness dimension were from participant D15-A. As we mentioned above, this participant disagreement reflected the difficulties s/he faced using the prototyping tool. However, this participant assigned a *totally agreed* answer the question U5 which, even having difficulties with the tool.

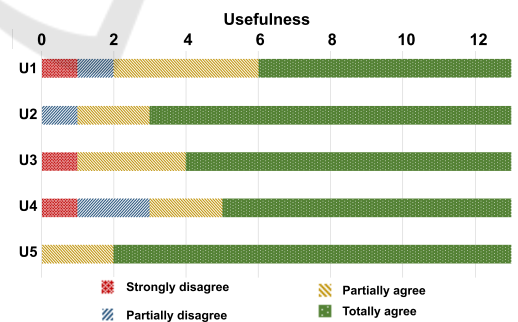


Figure 3: Participants’ feedback on the perceived usefulness.

5.3 Influence of Participants’ Profile in the Results

We decided to run the Fisher’s exact test (1922) to see whether the participants’ profile (i.e. their experience)

could influence on the acceptance of Vis2Learning and the selection of the correct chart. We took the Fisher's exact test because it allows comparing categorical data collected from small samples. It calculates the exact significance of the deviation from a null hypothesis using the *p-value*, while other methods use an approximation. In addition to providing a *p-value* with greater accuracy in small samples, the exact significance tests do not require a balanced or well-distributed sample (Mehta and Patel, 1996) which matches our sample's characteristics. A 95% (i.e. 0.05) confidence interval was considered to mitigate errors in the results⁵.

First, we checked the acceptance in the perspective of ease-of-use. In our test, we checked whether the previous experience with InfoVis could influence the acceptance of our guidelines. We thus defined the null and alternative hypothesis, taking into account the answers of questions F1 and F2 (see Table 6), as follows: *H0* - The previous knowledge of the participant on InfoVis has no influence in the acceptance, and *H1* - The previous knowledge of the participant on InfoVis has influence in the acceptance. We compiled the data for the test in Table 7. After running the Fisher exact test, we got a *p-value*=0.4615 to question F1 and *p-value*=0.8368 to question F2. The results suggest that there is no statistical evidence to support that having previous knowledge of InfoVis influence on the acceptance of the Vis2Learning.

Table 7: Previous knowledge on InfoVis vs feedback of acceptance.

| TAM question | Knowledge in InfoVis? | Strongly disagree | Partially disagree | Partially agree | Totally agree |
|--------------|-----------------------|-------------------|--------------------|-----------------|---------------|
| F1 | No | 0 | 0 | 4 | 1 |
| | Yes | 0 | 3 | 3 | 2 |
| F2 | No | 0 | 0 | 4 | 1 |
| | Yes | 1 | 1 | 3 | 3 |

In a second checking, we considered whether the fact of the participants are familiar with using charts could influence the construction of suitable visualizations. In this checking, we took data from groups A and B, about the visualizations produced for the scenarios SU1 and SU2 (see Table 5), and the participants' profile (see Table 4). Table 8 shows the compilation of these data. The null and alternative hypothesis were defined as follows: *H0* - The participant familiarity with visualizations did influence the selection of suitable chart, and *H1* - The participant familiarity with visualizations influenced the selection of suitable chart. Fisher exact test returns a *p-value*=0.3748 for SU1 and *p-value*=0.6652 for SU2. The results suggest that there is no statistical evidence that the par-

⁵We run tests from this website <https://astatsa.com/FisherTest/>.

icipant's familiarity with charts influenced the participants' choices for both scenarios.

Table 8: Familiarity with visualizations vs suitable solutions of visualizations.

| Scenario | Familiarity with visualizations? | Suitable visualization | Unsuitable visualization |
|----------|----------------------------------|------------------------|--------------------------|
| SU1 | No | 6 | 1 |
| | Yes | 12 | 7 |
| SU2 | No | 3 | 4 |
| | Yes | 11 | 8 |

Finally, we run the test to verify if experience in programming could impact the selection of the appropriate chart format by the participants. In this test we did not took the participants divided in groups (i.e. A or B). The data used is displayed in Table 9. The null and alternative hypotheses were defined as follows: *H0* - The level of experience in programming of the participant did not have an influence on the choice of the suitable chart format, and *H1* - The level of experience in programming of the participant did have an influence on the choice of the suitable chart format. We obtained the *p-value*=0.3821 for SU1, and the *p-value*=0.6828 for SU2 leading the rejection of null hypotheses. The results suggest that there is no statistical evidence that experience in programming helped the participants make appropriate choices of the charts.

Table 9: Experience in programming vs suitable visualizations.

| Scenario | Expert in programming? | Suitable visualization | Unsuitable visualization |
|----------|------------------------|------------------------|--------------------------|
| SU1 | No | 13 | 4 |
| | Yes | 5 | 4 |
| SU2 | No | 10 | 7 |
| | Yes | 4 | 5 |

6 DISCUSSION

Taking into account our RQ1 (*How did the participants in both groups build the visualizations?*), the results show that the participants who used the guidelines were more successful in building the solutions. These participants stated that they have never been in contact with similar guidelines. The participants that did not use the guidelines made more efforts in the construction of their visualizations as we saw from their quotes. They often took the trial and error approach, which led them to spend more time to build the solutions. We could also see that the participants did not have issues related to the accessibility of visualizations when this was not pointed out explicitly. This way, we believe that the guidelines need to evolve in order to properly address recommendations for accessibility.

Our results showed that the guidelines had a positive acceptance, i.e. our RQ2 (*What are the participants feedback about the guidelines?*). The participants' feedback considered our proposal as easy to use and usefulness to the development of visualizations of educational data. The participants pointed out that providing examples and recommendations aimed at to a context could better support the solution design. Concerning the participants' profile, we saw that these profiles did not have influence on the Vis2Learning acceptance as well as in the choice of the suitable chart.

By looking at the related work (see Section 2), we see that our proposal presents important contributions by providing guidelines related to data domain. Most of the related works proposed processes to conduct the development of visualizations for e-learning (Conde et al., 2015; Maldonado et al., 2015; Ruipérez-Valiente et al., 2017; Chen et al., 2016; Klerkx et al., 2017). Even though our related work section has presented works with proposals to the context of educational data, none of them provides recommendations regarding the type of visualization to be used. Others provided general guidelines not adherent to the context of educational data (Vicarelli et al., 2019). Our proposal differs from the related work by offering a set of guidelines for educational data-related context and also by supporting developers with application scenarios.

Taking into account that Munzner's recommendations (2014) are the most used in the literature, we decided to compare the similarities between our guidelines and Munzner's recommendations. To carry out a parallel between the two works, we extracted the rules from Munzner's book which are spread in different chapters. After that, we analyzed the links between our guidelines and Munzner's rules. We considered that there are similarities when our guidelines encompassed at least one of the rules. To characterize the strength of the link, we adopted an index ranging from 1 to 3 which was applied as follows: 1 - our guideline had the same purpose as a rule from Munzner's book; 2 - we applied concepts of a rule from Munzner's book but in a contextualized way to educational data; or 3 - our guideline partially presented aspects to those of a rule from Munzner's book.

Figure 4 illustrates the results of our comparison. We noticed that all the scenarios (i.e. X-axis) of our guidelines established at least one link (represented by bubbles) with Munzner's rules (i.e. Y-axis). We see that 18 of the 35 links are characterized by index 2 (i.e. red bubble), indicating that our proposal covers the rules. This result shows that our guidelines follows the best practices for constructing visu-

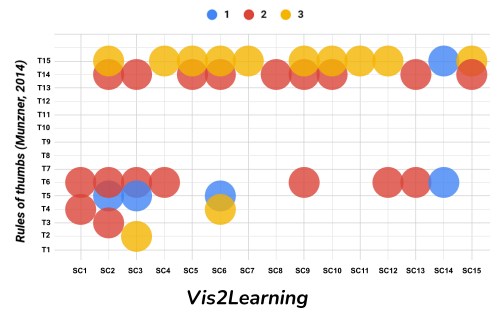


Figure 4: Comparison between our guidelines and rules of thumbs (Munzner, 2014).

alizations, however, it is concerned on applying them into the context of educational data. The guidelines SC2, SC3, SC6 and SC9 stand out, because each of them incorporates three or more aspects of Munzner's rules.

7 CONCLUSION AND FUTURE WORK

In this paper, we presented a set of guidelines to support developers and designers in the development of visualizations in the educational context. Our proposal was evaluated by 26 participants. We analyzed the results in three perspectives: (1) how the participants constructed visualizations (in the educational context), whether using or guidelines or not; (2) The participants' feedback, regarding the acceptance of our guidelines and; (3) The influence that the participants' profile had on building suitable visualizations.

The results allowed us to conclude that our guidelines helped the participants to focus on the construction of visualization related to the data domain (i.e. educational context), and on important details that improve the users' perception on the information. In addition, our guidelines work on the participants conscious of the importance of considering users' interaction with the visualization and not just the chart format, when building the visualizations. Finally, the participants show positive perceptions regarding the the guidelines' easy-of-use and usefulness. From statistical testings, we noticed that the participants' profile did not influence the construction of suitable solutions, which reinforces the idea that our guidelines are applicable to their purposes.

However, from our evaluation, we could notice that our guidelines require some improvements to address accessibility issues. We intend to extend our guidelines by adding items related to accessibility as further work, running additional evaluation with developers in the industry.

ACKNOWLEDGMENTS

The authors would like to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001 and the Conselho Nacional de Desenvolvimento Científico e Tecnológico - Brasil (CNPq grants 313312/2019-2 and 308395/2020-4).

REFERENCES

- Card, S. and Jacko, J. A. (2012). *Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications, Third Edition*. CRC Press, Boca Raton, FL, USA.
- Card, S., Mackinlay, J., and Shneiderman, B. (1999). *Readings in Information Visualization: Using Vision To Think*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.
- Carneiro, G. d. F. and Mendonça, M. G. d. (2013). Sourceminer - a multi-perspective software visualization environment. In *Proceedings of the 15th International Conference on Enterprise Information Systems - Volume 2: ICEIS*, pages 25–36. INSTICC, SciTePress.
- Chen, Y., Chen, Q., Boyer, S., Veeramachaneni, K., and Qu, H. (2016). Dropoutseer: Visualizing learning patterns in massive open online courses for dropout reasoning and prediction. In *2016 IEEE Conference on Visual Analytics Science and Technology (VAST)*, pages 111–120.
- Conde, M. A., García-Peñalvo, F. J., Gómez-Aguilar, D., and Therón, R. (2015). Exploring software engineering subjects by using visual learning analytics techniques. *IEEE Journal of Latin-American Learning Technologies*, 10(4):242–252.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Q.*, 13(3):319–340.
- Fisher, R. A. (1922). On the interpretation of χ^2 from contingency tables, and the calculation of p . *Journal of the Royal Statistical Society*, 85(1):87–94.
- Jordão, V., Gonçalves, D., and Gama, S. (2014). Eduvis: Visualizing educational information. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, NordiCHI '14, page 1011–1014, NY, USA. ACM.
- JUSTINMIND (2020). 8 data visualization tools for ux designers. <https://www.justinmind.com/blog/8-data-visualization-tools-for-ux-designers-visualize-insights-prototype-better-products>. Accessed: 2020-10-22.
- Klerkx, J., Verbert, K., and Duval, E. (2017). Learning analytics dashboards. In Lang, C., Siemens, G., Wise, A. F., and Gašević, D., editors, *The Handbook of Learning Analytics*, page 143–150. Society for Learning Analytics Research, Alberta, Canada.
- Macedo, M. P., Paiva, R. O. A., Gasparini, I., and Zaina, L. A. M. (2020). Vis2learning: A scenario-based guide of recommendations for building educational data visualizations. In *Proceedings of the 19th Brazilian Symposium on Human Factors in Computing Systems, IHC '20*, New York, NY, USA. Association for Computing Machinery.
- Majumdar, R. and Iyer, S. (2016). isat: a visual learning analytics tool for instructors. *Research and Practice in Technology Enhanced Learning*, 11(16).
- Maldonado, R. M., Pardo, A., Mirriahi, N., Yacef, K., Kay, J., and Clayphan, A. (2015). The latux workflow: Designing and deploying awareness tools in technology-enabled learning settings. In *Proceedings of the Fifth International Conference on Learning Analytics And Knowledge, LAK '15*, pages 1–10, New York, NY, USA. ACM.
- Mehta, C. and Patel, N. (1996). *SPSS exact tests*.
- Munzner, T. (2014). *Visualization analysis and design*. A.K. Peters visualization series. A K Peters.
- Park, Y.-G., Cho, Y.-S., and Son, J.-E. (2017). Design of a learning analytics dashboard based on digital textbooks and online learning. In *Workshop Proceedings of the 25th International Conference on Computers in Education*, pages 326 – 334. Asia-Pacific Society for Computers in Education.
- Reyes, J. A. (2015). The skinny on big data in education: learning analytics simplified. *TechTrends*, 59:75–80.
- Ruipérez-Valiente, J. A., Merino, P. J. M., Gascon-Pinedo, J., and Delgado-Kloos, C. (2017). Scaling to massiveness with analyse: A learning analytics tool for open edx. *IEEE Transactions on Human-Machine Systems*, 47(6):909–914.
- Salman, I., Misirli, A. T., and Juristo, N. (2015). Are students representatives of professionals in software engineering experiments? In *2015 IEEE/ACM 37th IEEE International Conference on Software Engineering*, volume 1, pages 666–676.
- Schwendimann, B. A., Rodríguez-Triana, M. J., Vozniuk, A., Prieto, L. P., Boroujeni, M. S., Holzer, A., Gillet, D., and Dillenbourg, P. (2017). Perceiving learning at a glance: A systematic literature review of learning dashboard research. *IEEE Transactions on Learning Technologies*, 10(1):30–41.
- Tervakari, A. M., Silius, K., Koro, J., Paukkeri, J., and Pirttilä, O. (2014). Usefulness of information visualizations based on educational data. In *2014 IEEE Global Engineering Education Conference, EDUCON*, page 142–151, NY, USA. IEEE.
- Victorelli, E. Z., Reis, J. C. d., Santos, A. A. S., and Schiozer, D. J. (2019). Design process for human-data interaction: Combining guidelines with semio-participatory techniques. In *Proceedings of the 21st International Conference on Enterprise Information Systems - Volume 2: ICEIS*, pages 410–421. INSTICC, SciTePress.
- Vieira, C., Parsons, P., and Byrd, V. (2018). Visual learning analytics of educational data: a systematic literature review and research agenda. *Computers & Education*, 122:119–135.
- Ware, C. (2012). *Information Visualization: perception for design*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 3 edition.
- Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., and Wesslén, A. (2012). *Experimentation in Software Engineering*. Springer Publishing Company, Incorporated, USA.