Towards a Teacher-Oriented Framework of Visual Learning Analytics by Scenario-Based Development*

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Abstract

Visual Learning Analytics (VLA) tools (such as dashboards) serve as a centralized hub for monitoring and analyzing educational data. Dashboards can assist teachers in data-informed pedagogical decision-making and/or students in following their own learning progress. However, the design of VLA tools should include features of trust in order to make analytics overt among its users. In this study, we propose a framework for the development of VLA tools from beginning to end that describes how we intend to develop the digital and technical infrastructure in our project for teachers. With that aim, we offer one scenario describing how data is managed, transferred, analyzed, and visualized by teachers. The suggested framework intends to make it easier for developers to understand the various steps involved in co-designing and developing a reliable VLA tool and to comprehend the importance of the teacher's participation in design. VLA tools developed based on the proposed framework have the potential to assist teachers in understanding and analyzing educational data, monitoring students' learning paths based on their learning outcomes and activities, simplifying regular tasks, and giving teachers more time to support teaching/learning and growth.

Keywords

Visual Learning Analytics Tool, Scenario-based Development, VLA Development Framework, Educational Data

1. Introduction

In the educational domain, the use of digital technology has allowed for the collection of a wide range of data on students. Educational data can be large, complex, and heterogeneous [1], coming from sources such as text, quizzes, timestamps, and behavioral data on the use of Digital Learning Material (DLM) or student data of an administrative nature from digital administrative systems. In this study, DLM refers to all digital materials that hold an educational purpose and are accessible through a computer or a tablet. Due to the fact that educational data are typically spread over a variety of different digital resources, it may be challenging for a teacher to use them strategically for pedagogical data-informed decision-making.

Once the educational and administrative data (student data such as grades and attendance) is safely moved to a unified storage, matched, and anonymized, a process for extracting insights (such as identifying a student's learning path, monitoring and predicting their performance, comparing individuals, organizing students in groups in a classroom, etc.) from it is necessary. Learning Analytics (LA) was established to assist in the understanding of student data [2, 3]. LA is defined by Siemens et al. [4] (p. 1) as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs". As a developing area, LA draws pedagogical patterns from data related to a learner's interactions and activities to guide decision-making and assessments [5].

Visual Learning Analytics (VLA) tools visualize data (usually via dashboards) to help teachers better understand LA [1, 6, 7]. The definition of a VLA tool given by Schwenimann et al. [8] is "a single display that aggregates different indicators about learner(s), learning process(es), and/or learning context(s) into one or multiple visualizations". By using VLA tools, one may create a visual depiction of what a teacher or student can do to enhance motivation, self-direction, learning effectiveness, student performance, and teacher engagement [9, 10, 11]. However, for the successful integration and effective utilization of analytics in supporting learning and teaching, the design of VLA tools should consider a spectrum of human factors, encompassing the reasons behind their usage and the methods by which they will be applied [12, 13]. In addition, the functionality of analytics challenges the accountability of students' learning processes that are simply transformed into non-transparent processes for teachers [14], requiring therefore other design components of trust not addressed before. The research question that drives our work is formulated as follows:

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How can a VLA development framework be used to establish a digital and technical infrastructure for primary and secondary school teachers? We chose to work with primary and secondary school teachers because there is little research on VLA tools in this context [10]. Our proposed framework goes through a detailed scenario that includes: 1) the different steps required in co-designing and developing a reliable VLA tool; 2) the long-term engagement necessary to build a solution based on the actual needs and trade-offs that design decisions can amount to; 3) the educational data collected from various resources required for creating a more comprehensive overall view of the students' learning and learning process; and 4) the necessary building blocks required for the construction of a technological solution that is transparent to the user. Developing a VLA tool based on the suggested framework that incorporates all data gathered from numerous stakeholders and adheres to the same data structure has the potential to streamline everyday activities and provide teachers with more time to support students' growth and learning [15].

The rest of the article is organized as follows. Section 2 describes the background of the scenario-based models. Section 3 describes the elements of the digital and technical infrastructure. Section 4 presents the user scenario. Section 5 concludes the paper.

2. Background

In the study by Buckingham Shum et al. [12], they presented principles of Human-Centered Design (HCD) from related fields that can be incorporated and customized to facilitate the advancement of human-centered learning analytics. Furthermore, Dimitriadis et al. [16] presented three HCD principles for LA solutions, including positioning teachers and other stakeholders as agents, incorporating the learning design cycle into the LA design process, and leveraging educational theories to inform the design and implementation of LA solutions. Within the larger context of HCD, scenario-based management and policy support technologies can serve as valuable assets. Scenarios play a ubiquitous role in the software development process and hold significance for any system operating in a complex environment, extending beyond systems solely reliant on human-computer interfaces [17, 18]. In requirements engineering, scenarios promote multidisciplinary learning, but they also serve as a mechanism for labor division, with significant consequences for project management and artifact integration [19]. According to Polasky et al. [20], scenarios are "sets of plausible stories, supported with data and simulations, about how the future might unfold from current conditions under alternative human choices". Scenarios are straightforward approaches that involve actively envisioning and documenting common and pivotal user activities early on and consistently throughout the development process which facilitate the analysis of usage situations, even before those situations come into existence [21, 22, 23]. For example, Siddiqui et al. [24] developed a scenario-based e-learning solution to improve the effectiveness of an introductory technology course. The scenarios' main goal is to enable decision-makers to consider the consequences of different assumptions of how systems might respond to various causes of change [25]. For instance, Zurek & Henrichs [26] have claimed that scenarios can be used to: 1) help us structure the choices we need to make by identifying any potential long-term consequences, 2) by giving people a place to consider the implications of different options in the face of upcoming uncertainty, a platform for strategic planning and decision-making is provided, 3) allowing stakeholders to express opposing viewpoints and opinions will help to facilitate their participation in the strategic formulation process.

In this paper, we provided a scenario-based framework that describes how data is managed, transferred, analyzed, and visualized for teachers in primary and secondary education. The purpose of the suggested user scenario is to demonstrate how teachers can be involved in the co-design of a VLA tool by considering the infrastructure, and relevant building blocks and bringing value to the educational system. Researchers may also use the entire infrastructure presented in the framework as a guideline for the development of a reliable VLA tool.

3. The Digital and Technical Infrastructure

There are a few necessary building blocks that make up the technical infrastructure. The term "building block" refers to a group of "components" that can include technical capabilities, services, standardized models, frameworks, and patterns and that are intended to address common infrastructure problems in a given focus area [27]. We considered the following five building blocks for the scenario: 1) **Authorization**: this building block intends to assist the remaining four building blocks by enabling standardized digital functions for secure information exchange. The digital infrastructure and services needed to securely and digitally authorize individuals, groups, and smart objects are included in the authorization building block; 2) **Traceability**: this building block aims to provide a framework for traceability, add to a shared list of specifications, and look into and create operational capabilities and processes for traceability; 3) **Trust framework**: by establishing requirements and monitoring capabilities for a trust-promoting environment, the framework for "organizational trust" intends to make it easier for stakeholders to establish and share digital information in a secure manner over a long term, 4) **API**: there should be preconditions in digital processes for co-creation between the public sector, individuals, and the private sector in a modern digital ecosystem where a large number of stakeholders (producers and consumers) participate with services and information cast in components for information interchange. Application Programming Interfaces (APIs) are essential in facilitating this information sharing. The defined standards and guidelines are made available through APIs, a building block that also provides associated applications, programming interfaces, and visualizations. 5) **Access control**: where there is a recommendation to ensure access (a login system) for an authorized user at the right time. These five building blocks described in this section are employed in the development of our VLA tool. The building blocks proposal intends to provide users—in this case, teachers— with secure access to information and a way to trace where the information is coming from. These enable the Development Team (DT) to monitor user access and exercise some control over the information's availability, but also show where the information comes from for teachers wanting to understand the "hidden" processes of the analyses.

The development phase of this project is carried out by considering a teacher scenario. Our scenario describes how data is managed, transferred, analyzed, and visualized for teachers. The purpose is to acknowledge the significance of the teacher's role in design and demonstrate how the relevant building blocks form the development of our VLA tool.

4. Scenario: "Rose is a teacher who wants to make pedagogical decisions based on digital data"

This scenario demonstrates what connections are established between the steps the teacher performs, the necessary building blocks that make up the infrastructure, and the datasets that feed into the infrastructure. In this scenario, Rose, a teacher ( ), knows that different digital tools provide different information about her students. However, those digital tools do not communicate with each other, as it is often the case with proprietary digital systems in primary and secondary education [28]. Rose is in a situation where she needs assistance in making pedagogical decisions and analyzing student data collected from the various digital resources that she uses in her teaching and learning activities. For properly evaluating the students' performance, she needs a mediating VLA tool—a dashboard—helping her to visualize and interpret the collected data. The user, Rose's activities in the scenario are shown in figure 1. This scenario includes

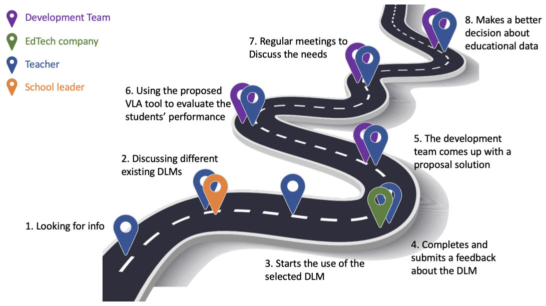

Figure 1: User activities for the teacher scenario.

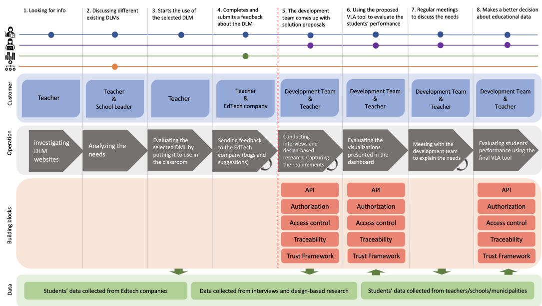

Figure 2: Workflow that describes Rose's need for a VLA tool (teacher dashboard).

8 steps, and as shown in Figures 1 and 2, the teacher participates in all eight steps of the scenario, while the Educational Technology (EdTech) company ( ) and the school leader ( ) are only involved in one. It should be noted that in this study we do not discuss the building blocks employed by the EdTech company for their DLM.

The first four steps of the scenario do not involve the DT ( ) that will create a VLA tool as well. The 8 steps of the scenario, shown graphically in Figure 2, are listed below:

1. *Looking for info*: Rose familiarizes herself with the websites of companies that produce DLM to investigate how she might motivate and help students improving their learning performance. She is also aware of the data collected by her school about her students.
2. *Discussing different existing DLMs*: because there are several DLMs, Rose requires the assistance of the school leaders, and perhaps even a representative from the school's IT department to discuss the matter, and to purchase a DLM. To accomplish that, she, and her colleagues, should analyze the needs and expectations of the teachers and the students, the possible integration of the DLM into the academic curriculum, the DLM's ease of use

and finally test different DLMs.

3. *Starts the use of the selected DLM*: Rose employs the purchased DLM in the classroom and evaluates it by considering the tasks and activities the students may complete with it. Using the DLM regularly allows the EdTech company to collect trustworthy data on the online activities and learning behavior of her students.
4. *Completes and submits feedback about the DLM*: since no DLM is perfect, Rose takes this step to provide feedback to the EdTech company every month addressing errors and bugs in the DLM or provide suggestions for how to improve the learning material.
5. *The development team comes up with solution proposals*: when developing a new digital tool, it is necessary to identify requirements [27, 29]. The DT identifies and analyzes the needs that Rose has and captures the requirements that should be featured in the tool for it to be safe and secure. To achieve this, the team first conducts Design-Based Research (DBR) [30] with Rose using paper and clickable prototypes [29] then interviews Rose to better understand her needs and the trade-offs that the team must apply for a viable design. This step needs to be repeated multiple times before the team is ready for the next step. After reviewing the data gathered from the interviews and the DBR, the team determines what data are required in the service. The DT identifies several sources of data that can be used to provide decision-making support to Rose, i.e., data from the DLM, as well as data collected in the administrative digital systems such as attendance, weekly academic schedule, learning objectives, etc. The team also considers how existing infrastructure building blocks might be linked to be used in conjunction with tool development.
6. *Using the proposed VLA tool to evaluate the students' performance*: The DT analyses the different datasets with machine learning techniques to discover more informative students' patterns in specific contexts. This step is done in strict collaboration with Rose, so that Rose can clearly understand the analysis performed and trust the developed VLA tool. Rose evaluates the visualizations of the relevant data. The data contains students' data from the EdTech company, DBR and interview data, and data regarding the students' progress and final grade gathered by Rose/school/municipality.
7. *Regular meetings to discuss the needs*: the DT meets with Rose to go over her requirements. Repeating this process a few times will allow the developer to create an efficient and trustworthy dashboard for her that meets all her requirements and encourages daily use.
8. *Makes a better decision about educational data*: the final step in the development phase will give Rose access to a teacher dashboard with visualizations that will assist her in better understanding the students' educational data collected from various resources, evaluating their performance, determining the best learning path, making better decisions, and assisting the students in improving their performance.

This scenario-based development helps to better comprehend the various steps involved in creating a reliable and trustworthy VLA tool and recognize the importance of the teacher's role in design as the primary user.

Developing a VLA tool by considering the proposed framework has the potential to streamline daily activities and offer teachers more time to support students' growth and learning [15]. The framework considers several datasets obtained from multiple sources such as schools' digital systems and EdTech companies and adheres to the same data structure. During the development of our dashboard, we have followed a scenario to help us detect all possible structures needed for the VLA tool. We are currently testing the dashboard in various schools and with many teachers, meaning we are on step 4, but we do not yet have preliminary results.

5. Conclusion

Today, many educational systems allow access to a large amount of information about students and their educational activities. However, it might be difficult to use these datasets strategically because they are usually dispersed across multiple distinct digital services. As a consequence, teachers fail to take advantage of the opportunity to make decisions based on evidence. In this study, we provided a VLA development framework that illustrates how we expect to develop the digital and technical infrastructure in our project. In order to achieve this and answer our research question, we provided a scenario for teachers that illustrates the use of data management, transfer, analysis, and visualization. The establishment of a VLA tool based on the suggested framework, which incorporates the information gathered from different datasets, has the potential to support teachers in understanding and analyzing educational data, monitoring students' learning paths based on their learning outcomes and activities, streamlining teachers' routine tasks, and finally giving teachers more time to support teaching/learning and development. We are currently engaged in a research project in collaboration with teachers, school principals and EdTech companies with which we are going to utilize the proposed framework to craft a solution that aligns with actual needs of teachers and considers design trade-offs.

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